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H04N 5/262

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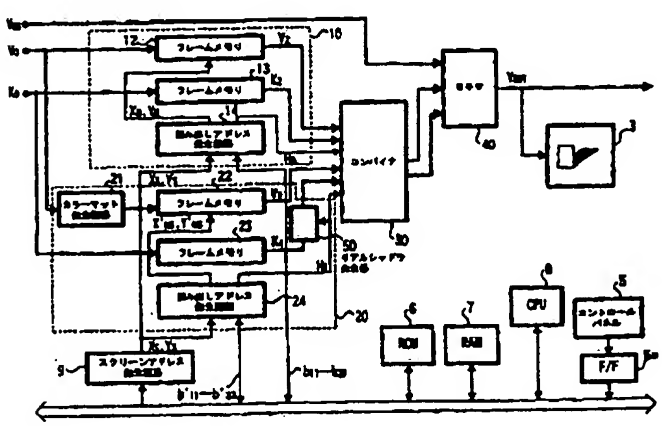
JP 630059276 A JP 070093585 A JP 050207364 A
JP 050054151 A JP 040315274 A JP 040227171 A
JP 020059982 A JP 010293078 A JP 010144869 A

(58) Field of Search by ISA
INT CL^{6} H04N 5/262
Jitsuyo Shinan Koho, 1926-1997; Kokai Jitsuyo Shinan Koho, 1971-1997

(54) Abstract Title
Special effect apparatus and special effect method

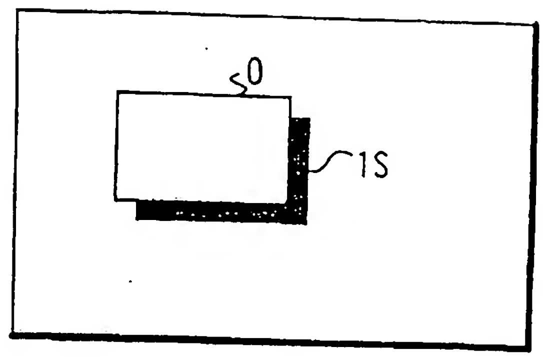
(57) A shadow closer to reality is added to an object image with a high speed with a simple construction and simple processings. A shadow video signal V_4 and a shadow key signal K_4 are generated by a shadow signal generating unit (20) and the shadow key signal K_4 is inputted to a real shadow signal generator (50), which generates a real shadow key by which a more realistic shadow is generated.



5 ... control panel
9 ... screen address generator
12, 13 ... frame memory
14, 24 ... reading address generator
21 ... color mat generator
22, 23 ... frame memory
30 ... combiner
40 ... mixer
50 ... real shadow generator

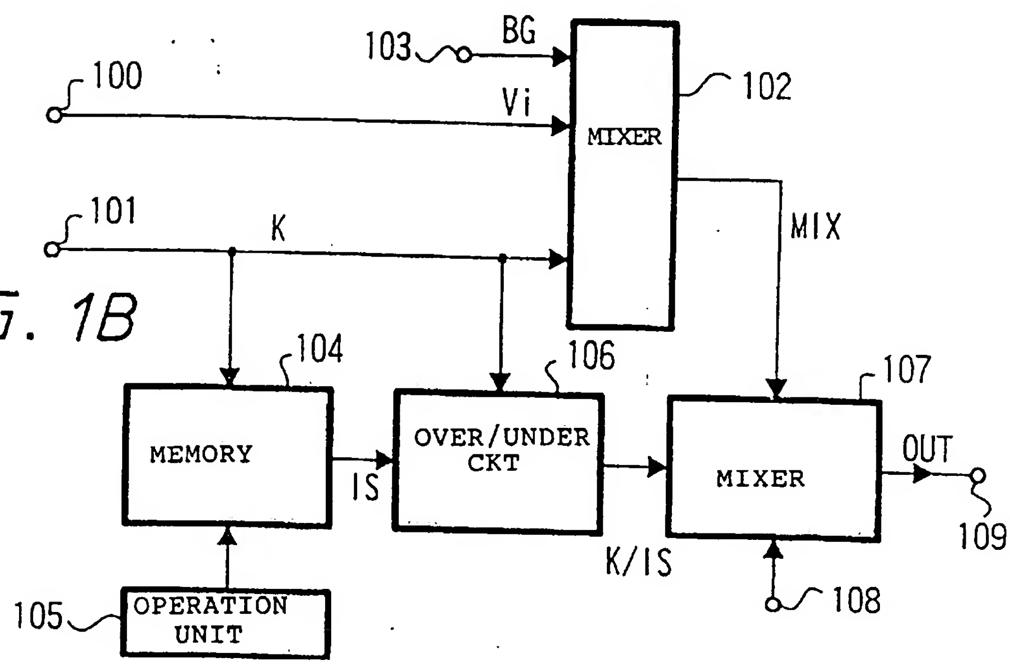
GB 2 329 312 A

FIG. 1A



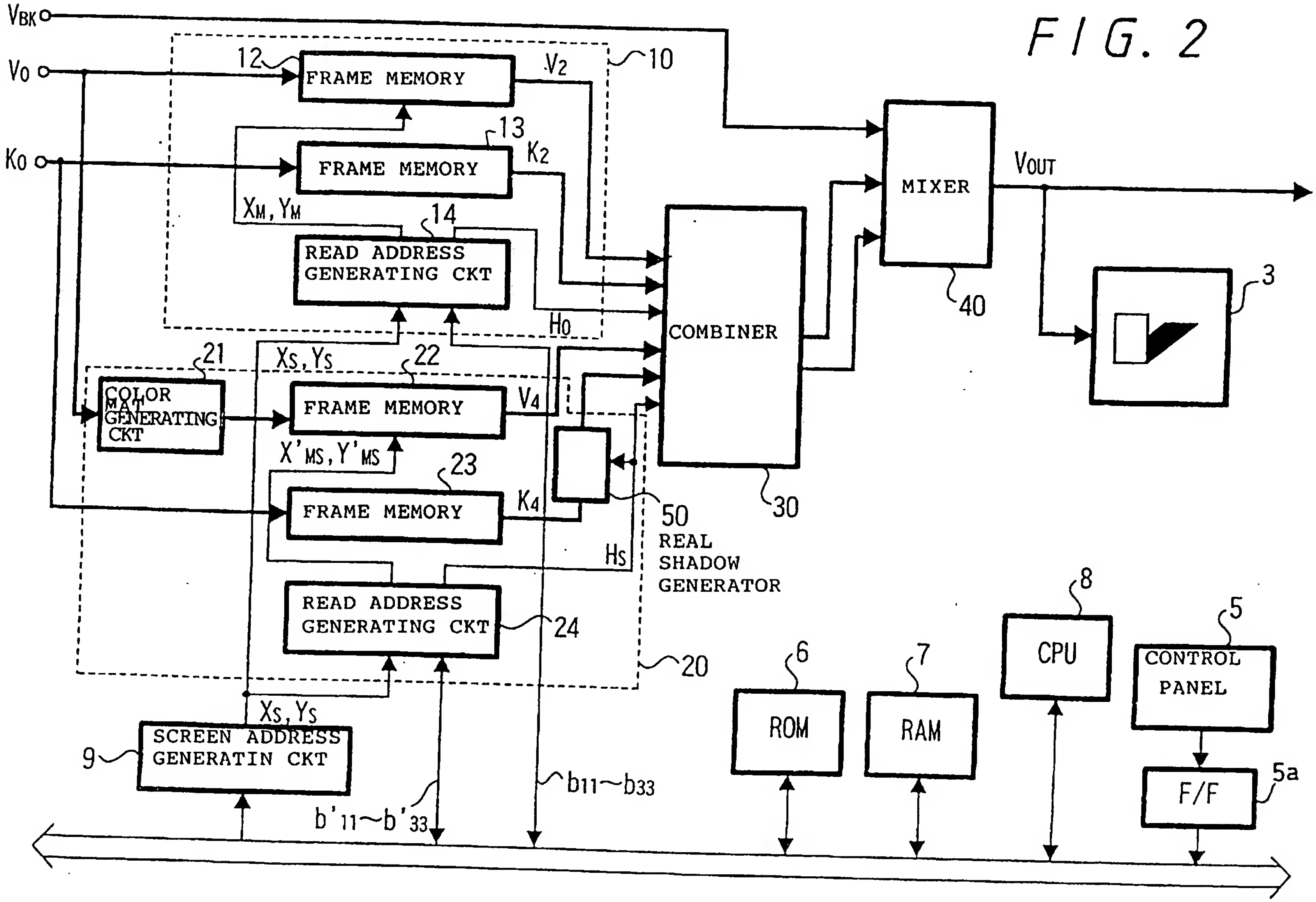
0
IS

FIG. 1B



103
BG
100
Vi
102
MIXER
101
K
MIX
104
106
107
MEMORY
OVER/UNDER CKT
MIXER
OUT
IS
109
K/IS
105
OPERATION UNIT
108

FIG. 2


VBK
V0
K0
FRAME MEMORY
FRAME MEMORY
READ ADDRESS GENERATING CKT
FRAME MEMORY
FRAME MEMORY
READ ADDRESS GENERATING CKT
COLOR MAT GENERATING CKT
SCREEN ADDRESS GENERATIN CKT
COMBINER
REAL SHADOW GENERATOR
MIXER
VOUT
CONTROL PANEL
F/F
CPU
RAM
ROM
V2
K2
H0
V4
K4
HS
XM, YM
XS, YS
X'MS, Y'MS
b11~b33
b'11~b'33
3
5
5a
6
7
8
9
10
12
13
14
20
21
22
23
24
30
40
50

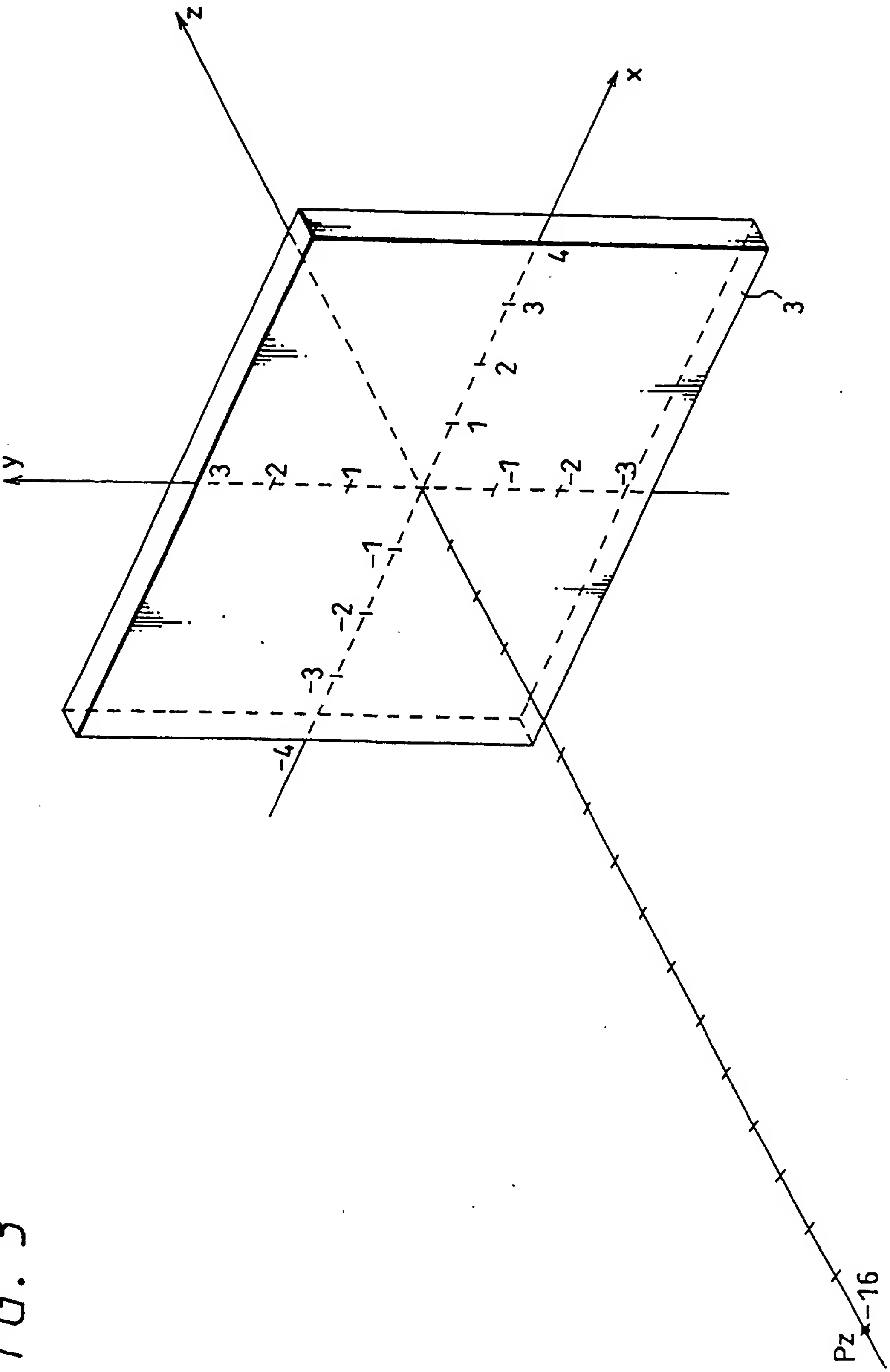
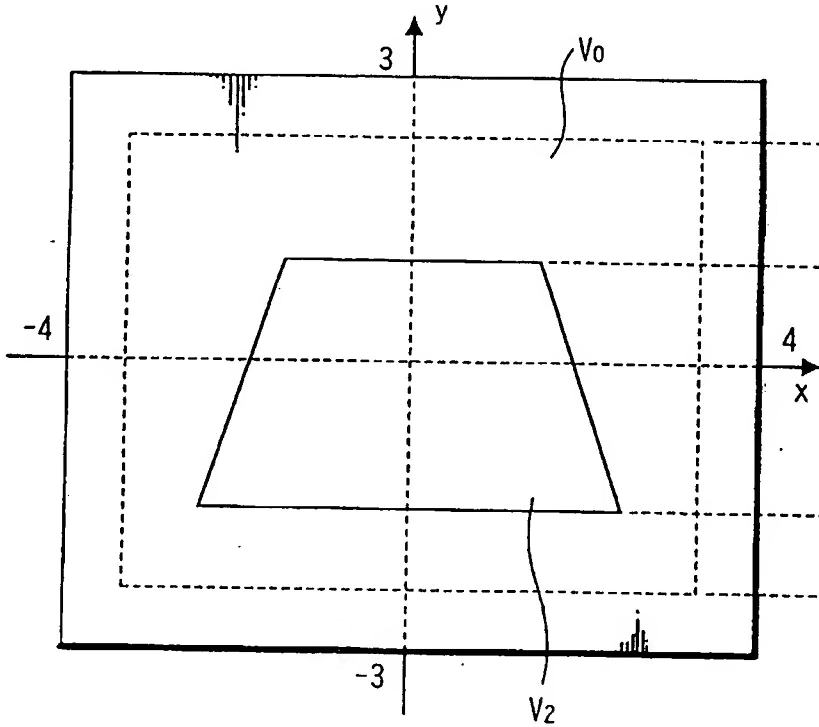
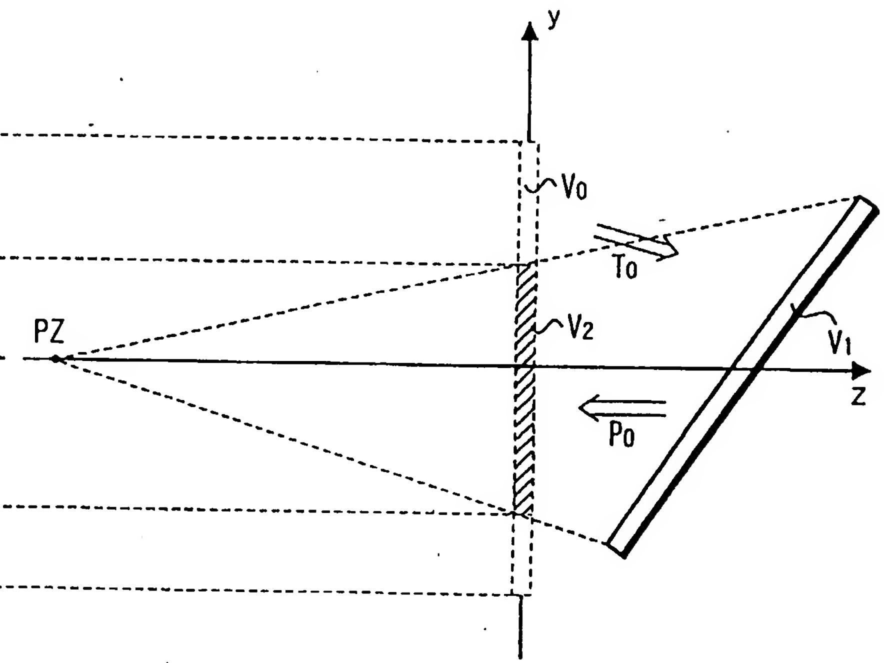


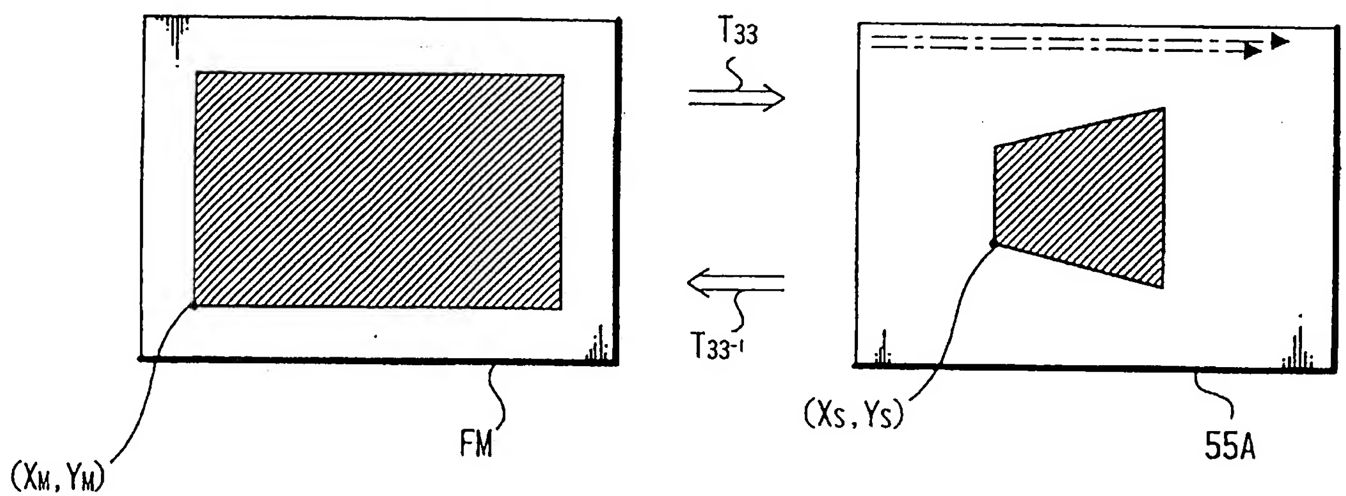
FIG. 3



F I G. 4A



F I G. 4B



F I G. 5A

F I G. 5B

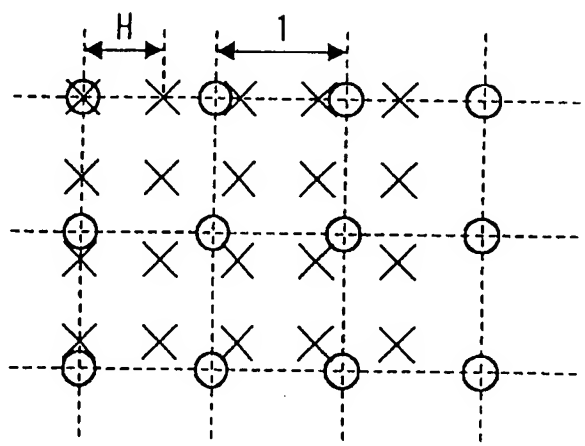


FIG. 6A

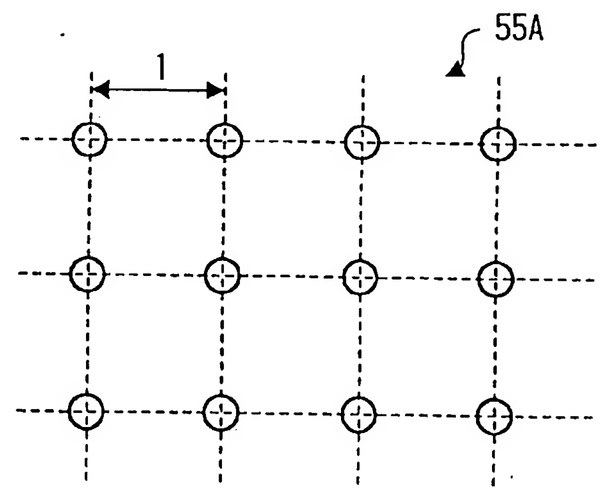


FIG. 6B

FIG. 7A

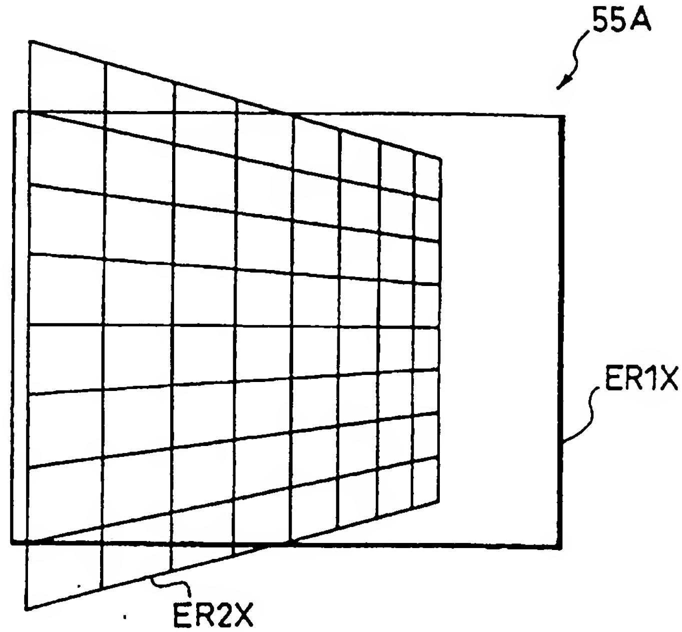


FIG. 7B

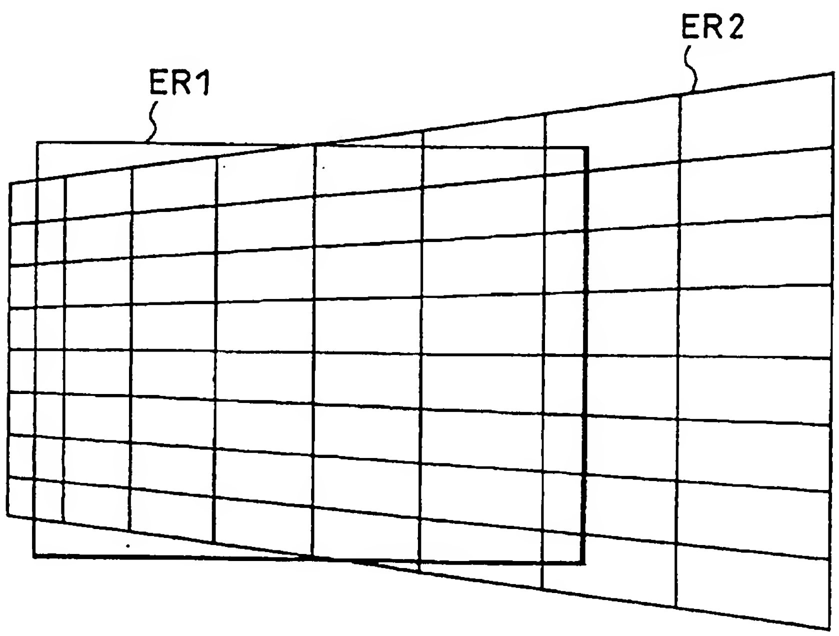
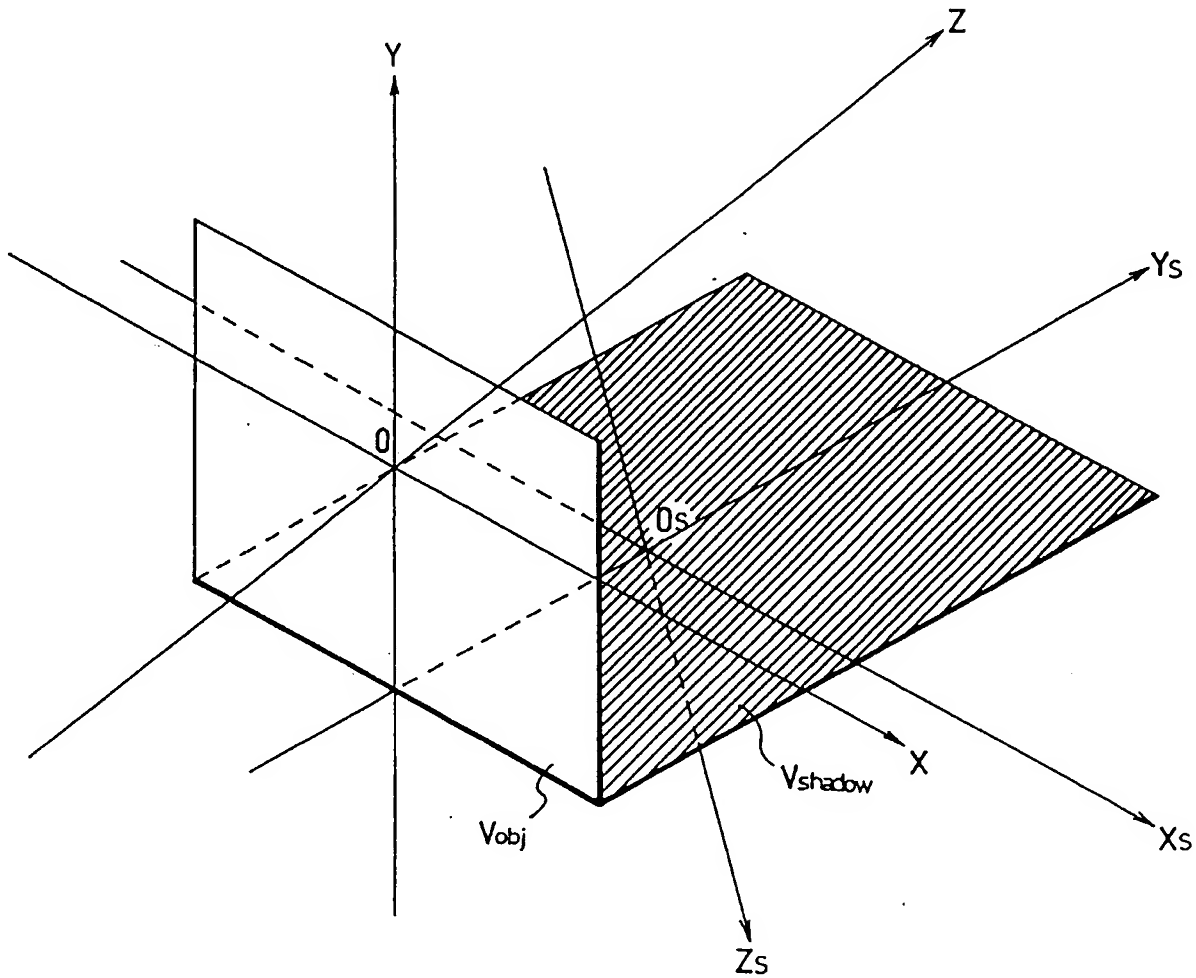


FIG. 8



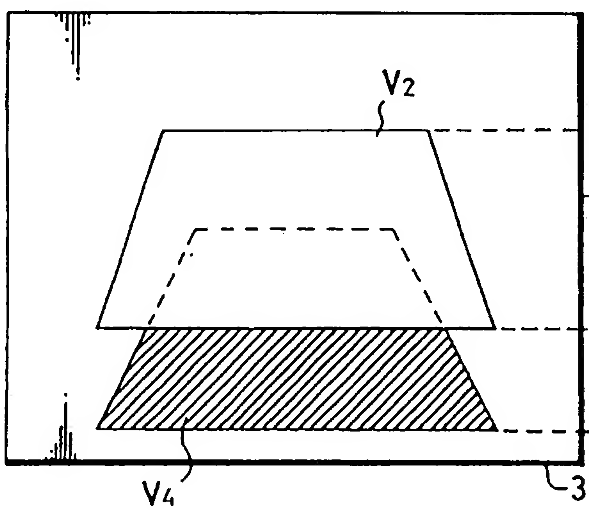


FIG. 9A

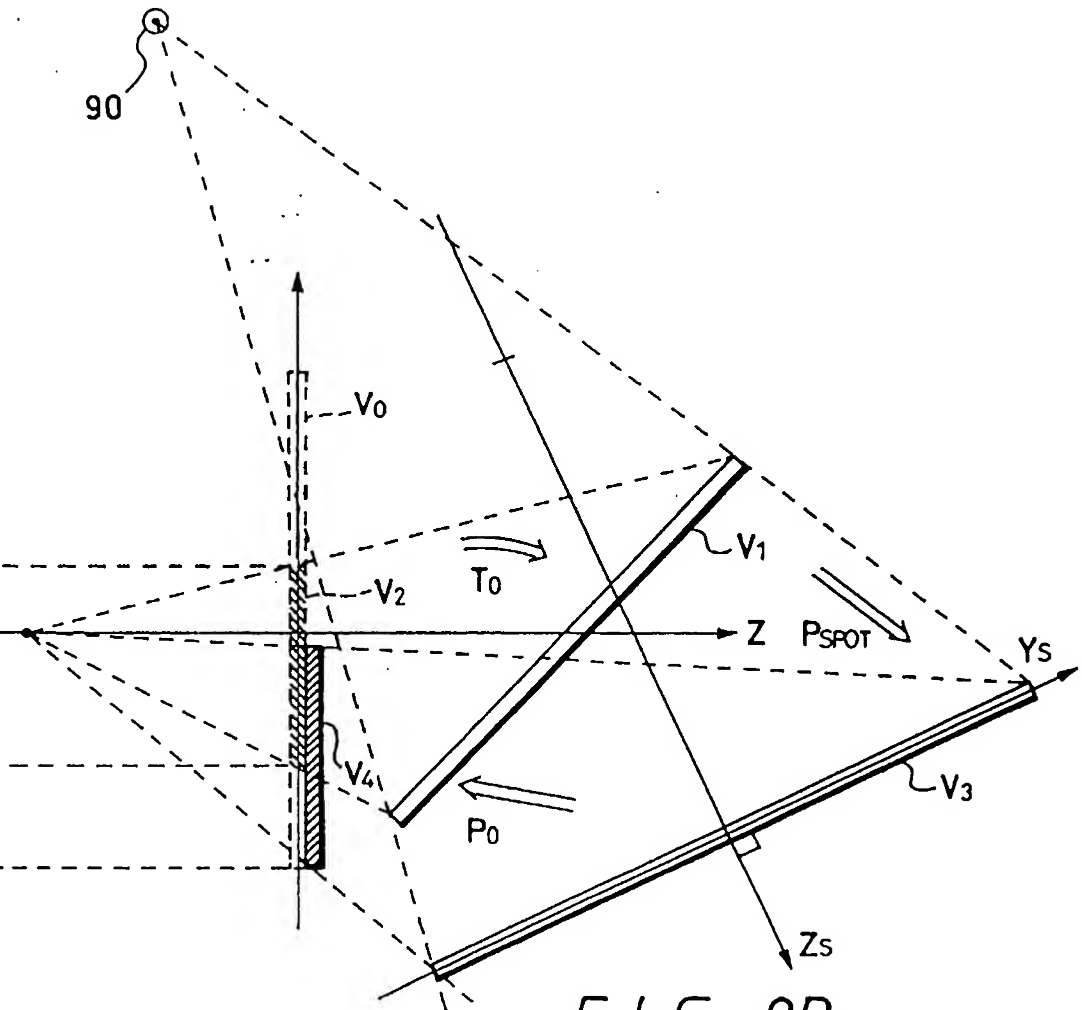
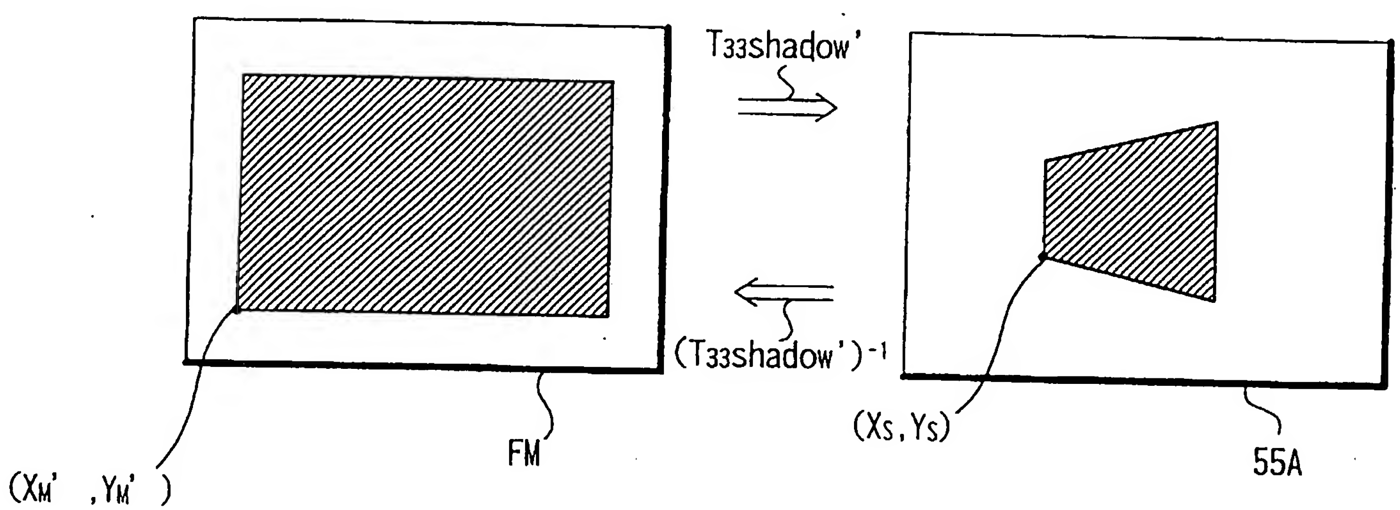


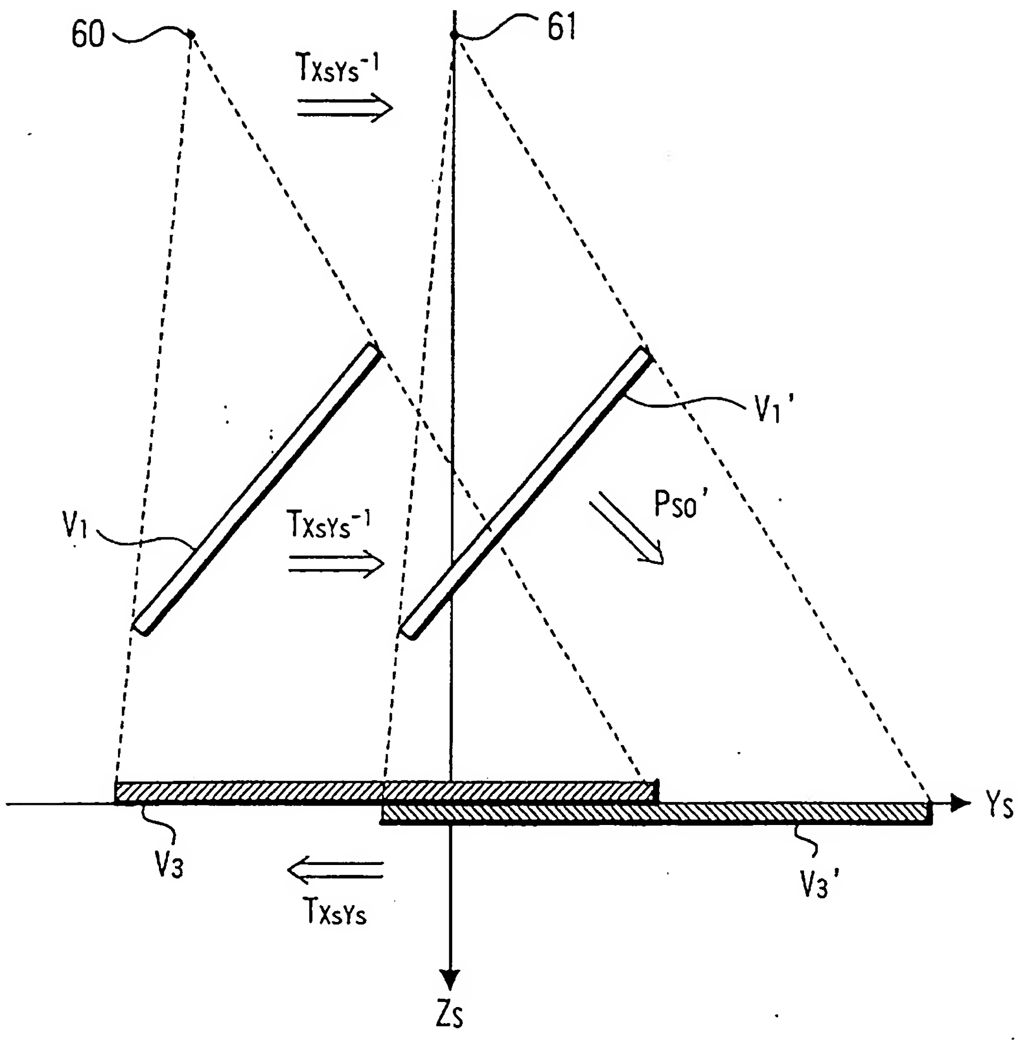
FIG. 9B

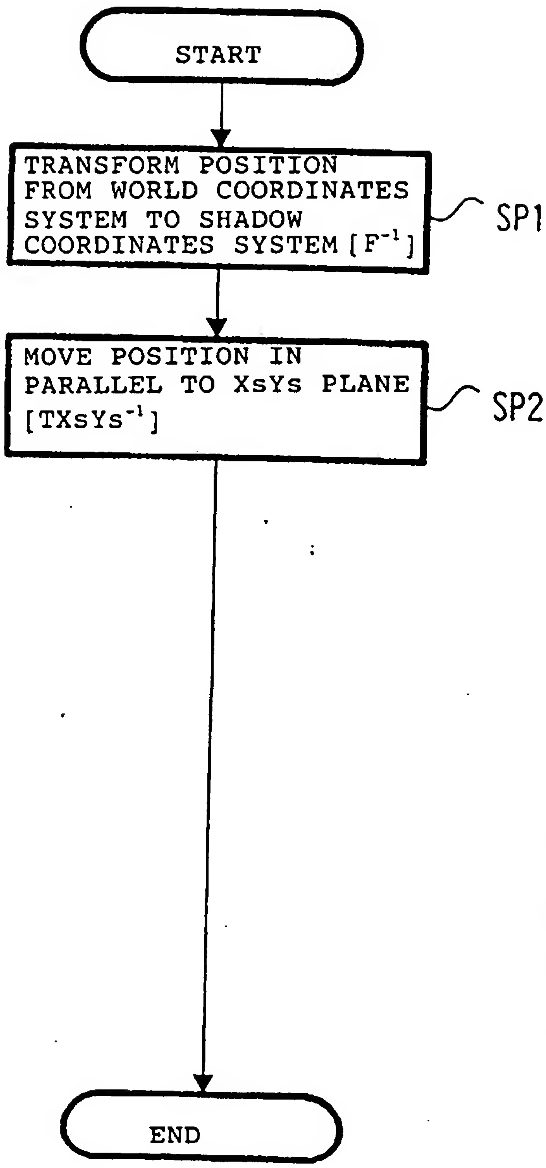


F I G. 9C

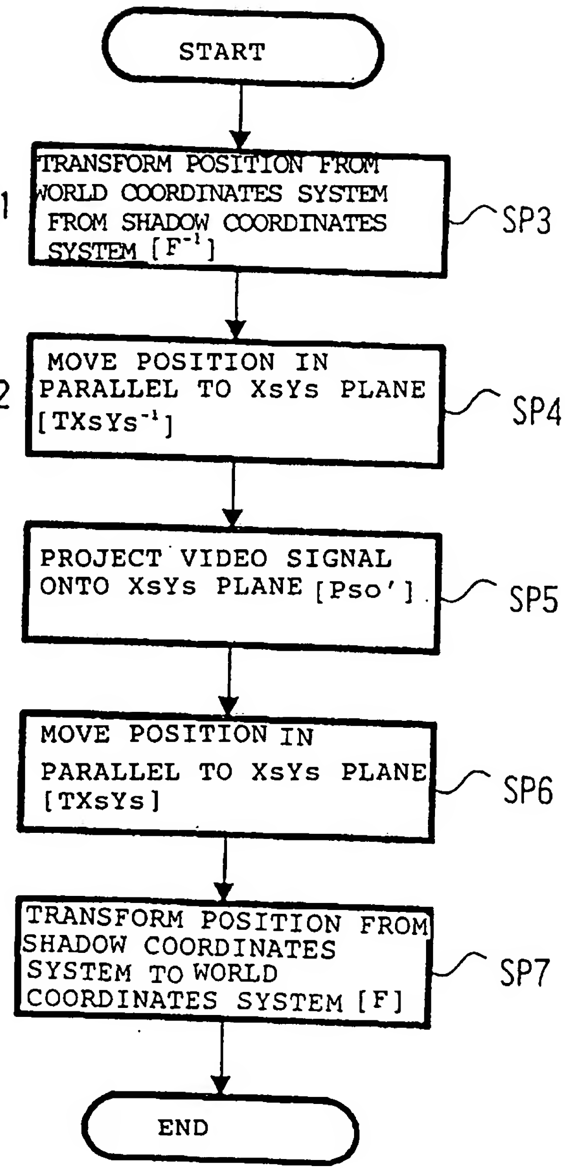
F I G. 9D

FIG. 10





F I G. 11A



F I G. 11B

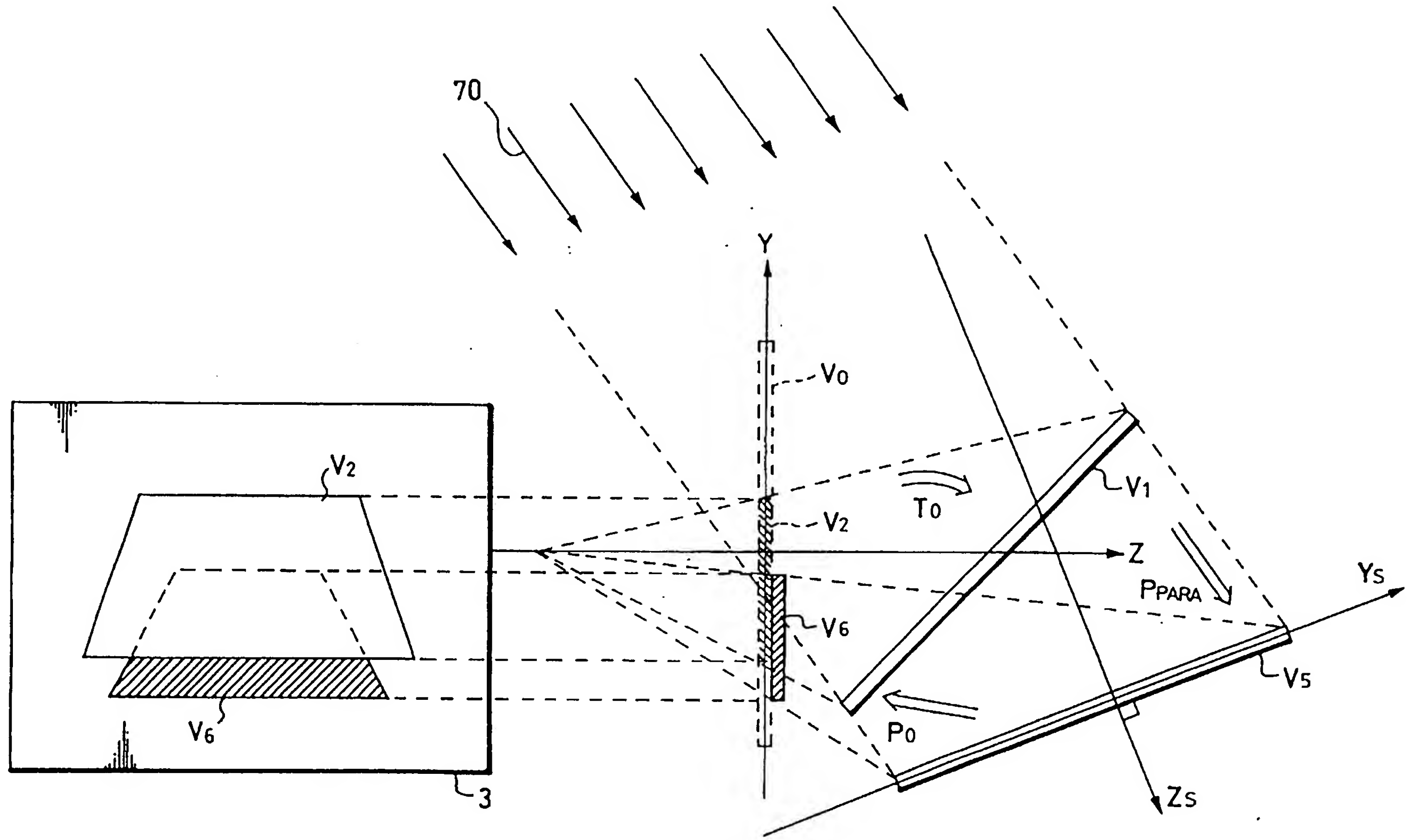
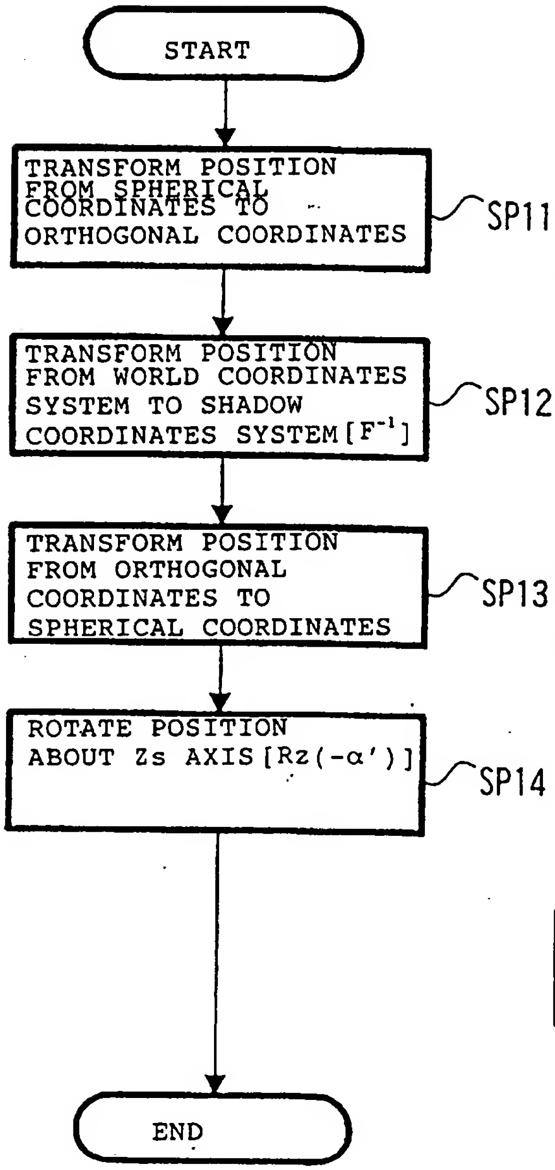
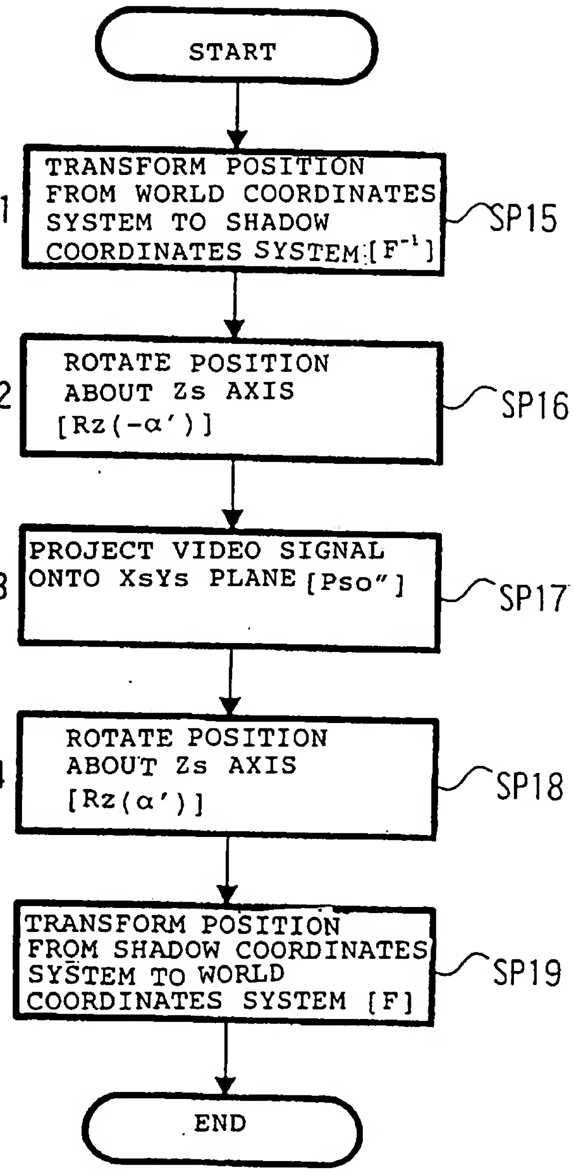


FIG. 12A

FIG. 12B



F I G. 13A



F I G. 13B

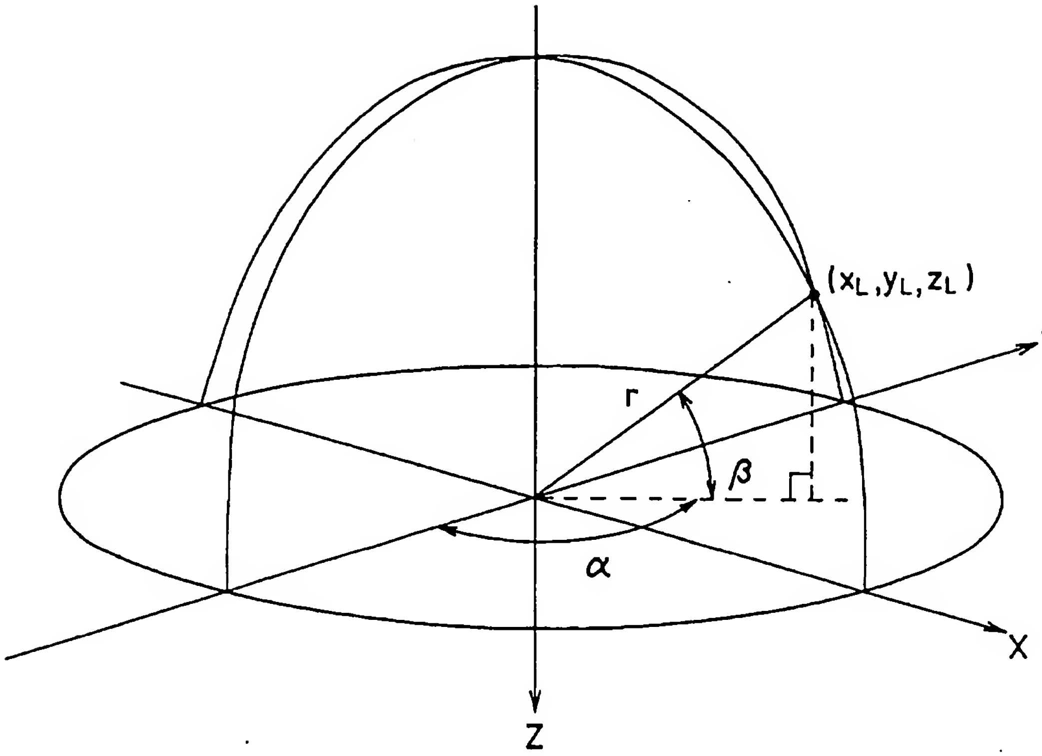


FIG. 14A

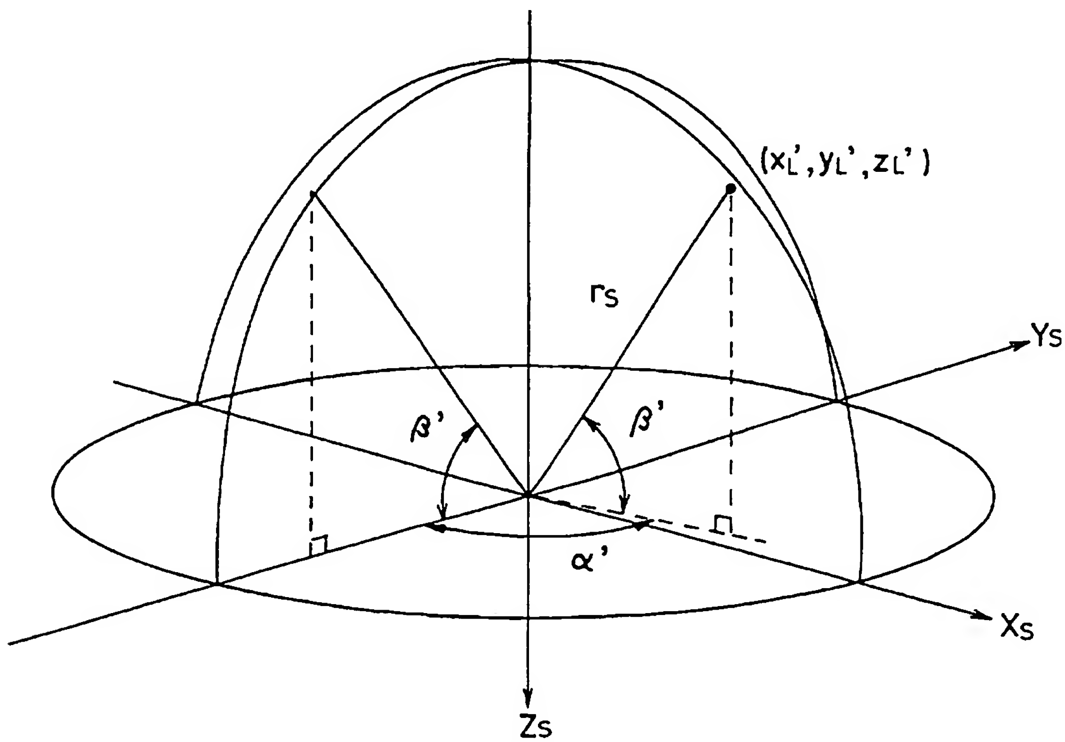
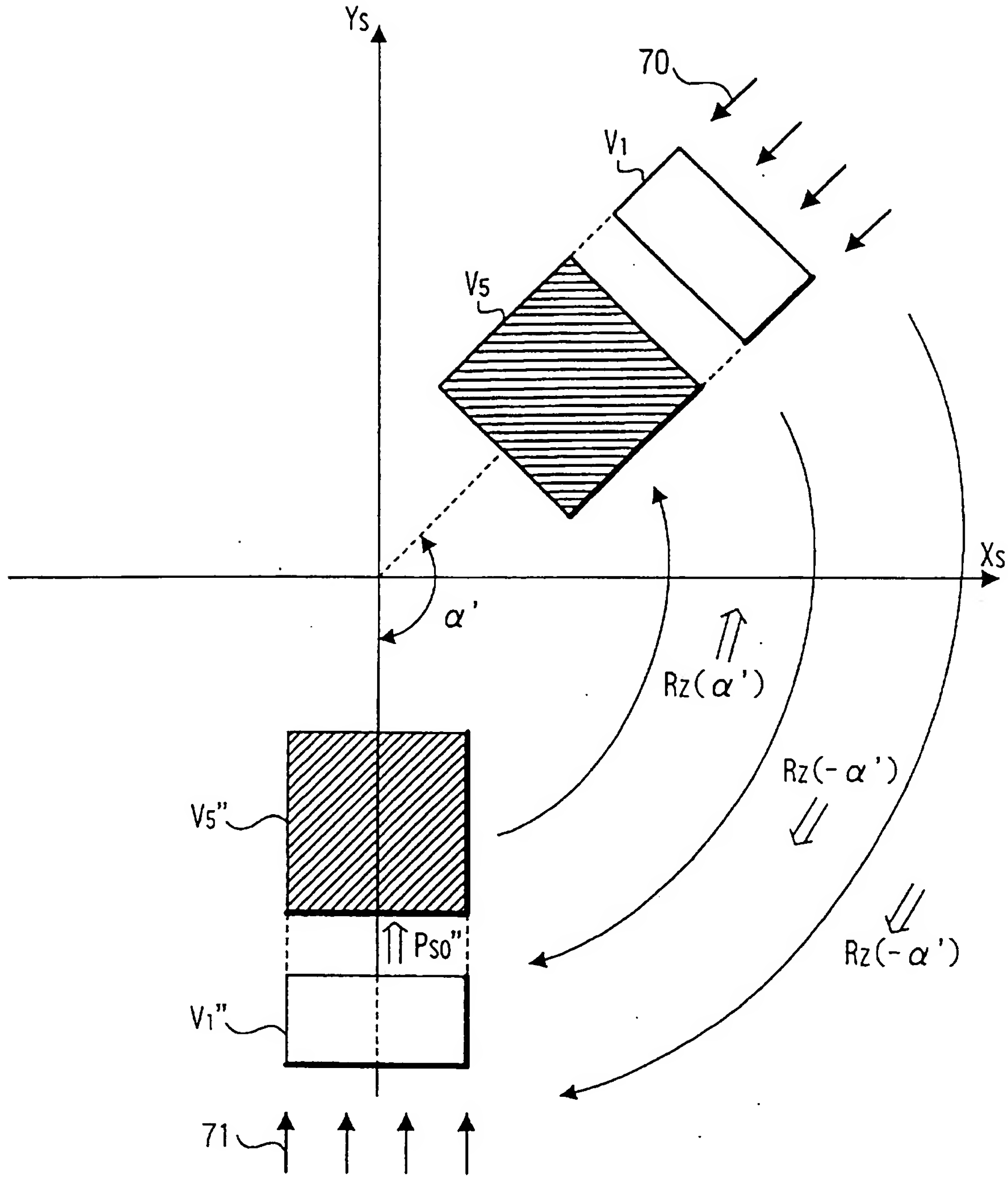
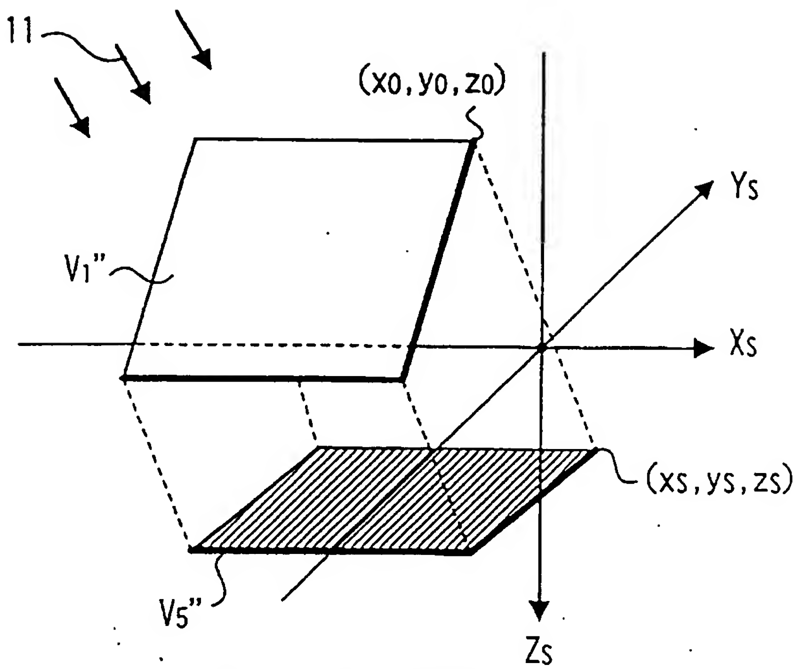


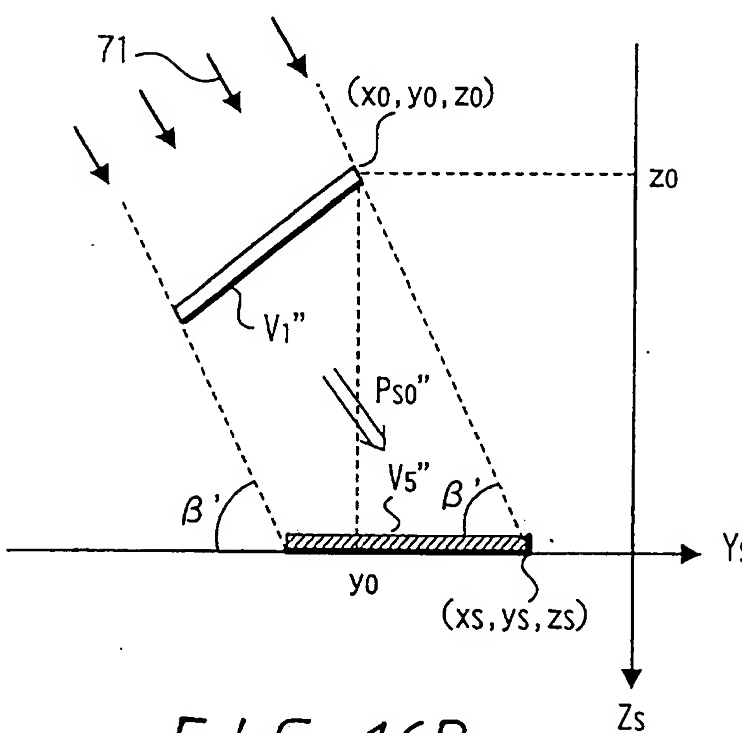
FIG. 14B

F I G. 15

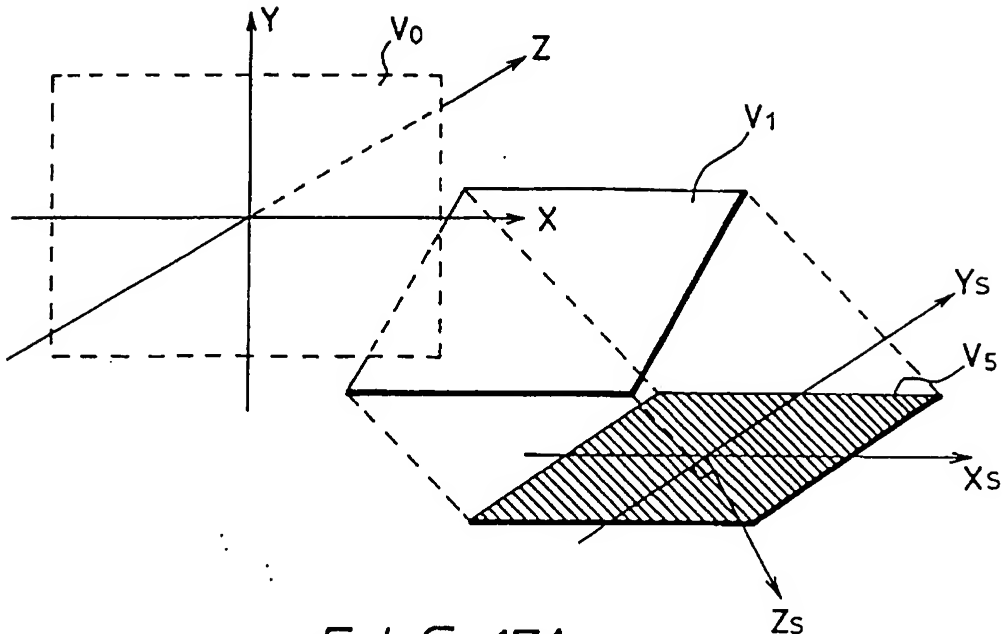




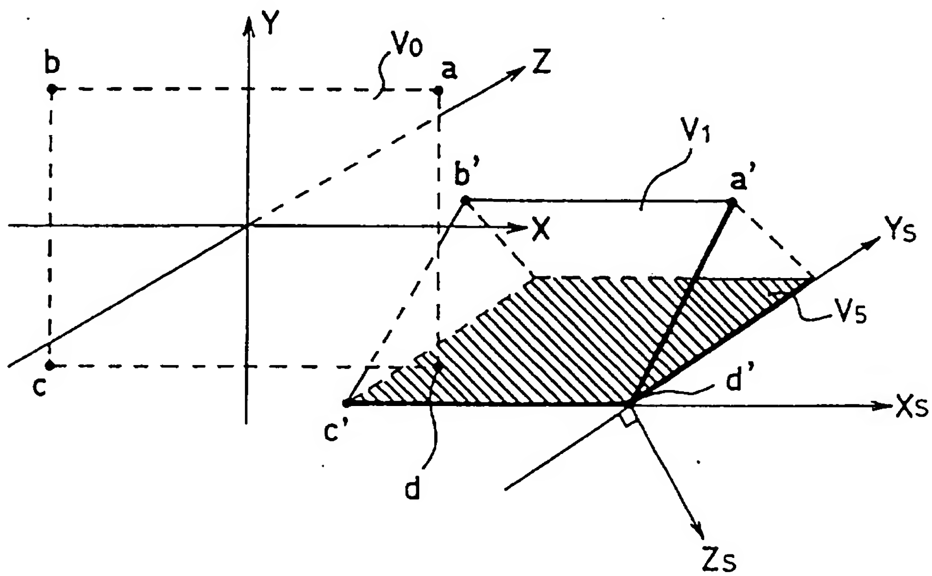
F I G. 16A



F I G. 16B

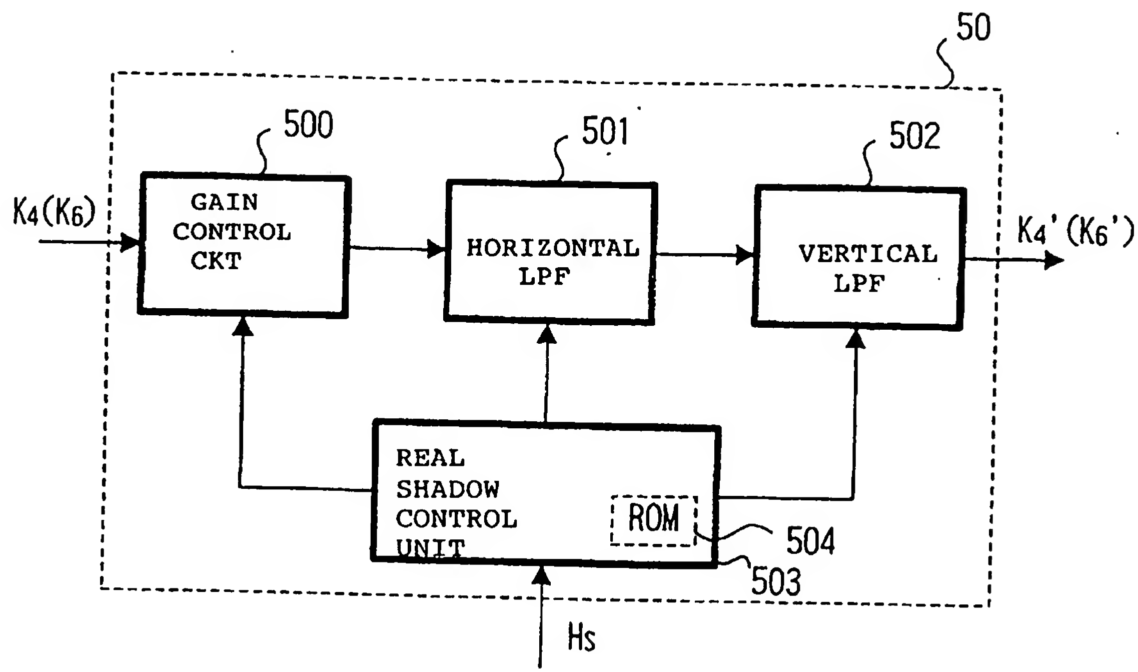


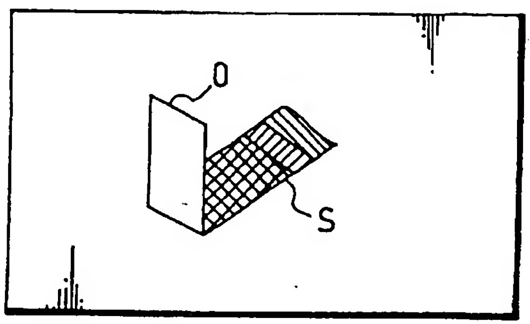
F I G.17A



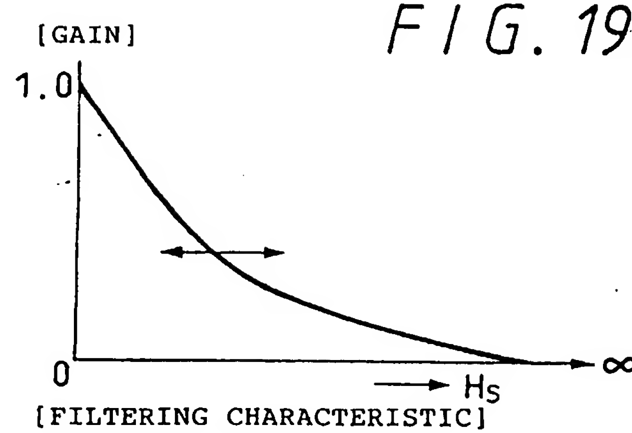
F I G.17B

FIG. 18

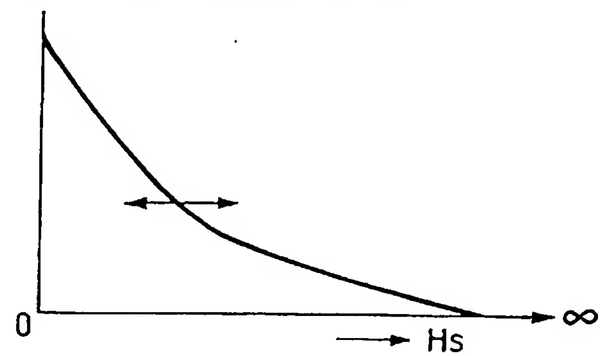

50
500
501
502
$K_4(K_6)$
GAIN CONTROL CKT
HORIZONTAL LPF
VERTICAL LPF
$K_4'(K_6')$
REAL SHADOW CONTROL UNIT
ROM
504
503
Hs



F I G. 19A

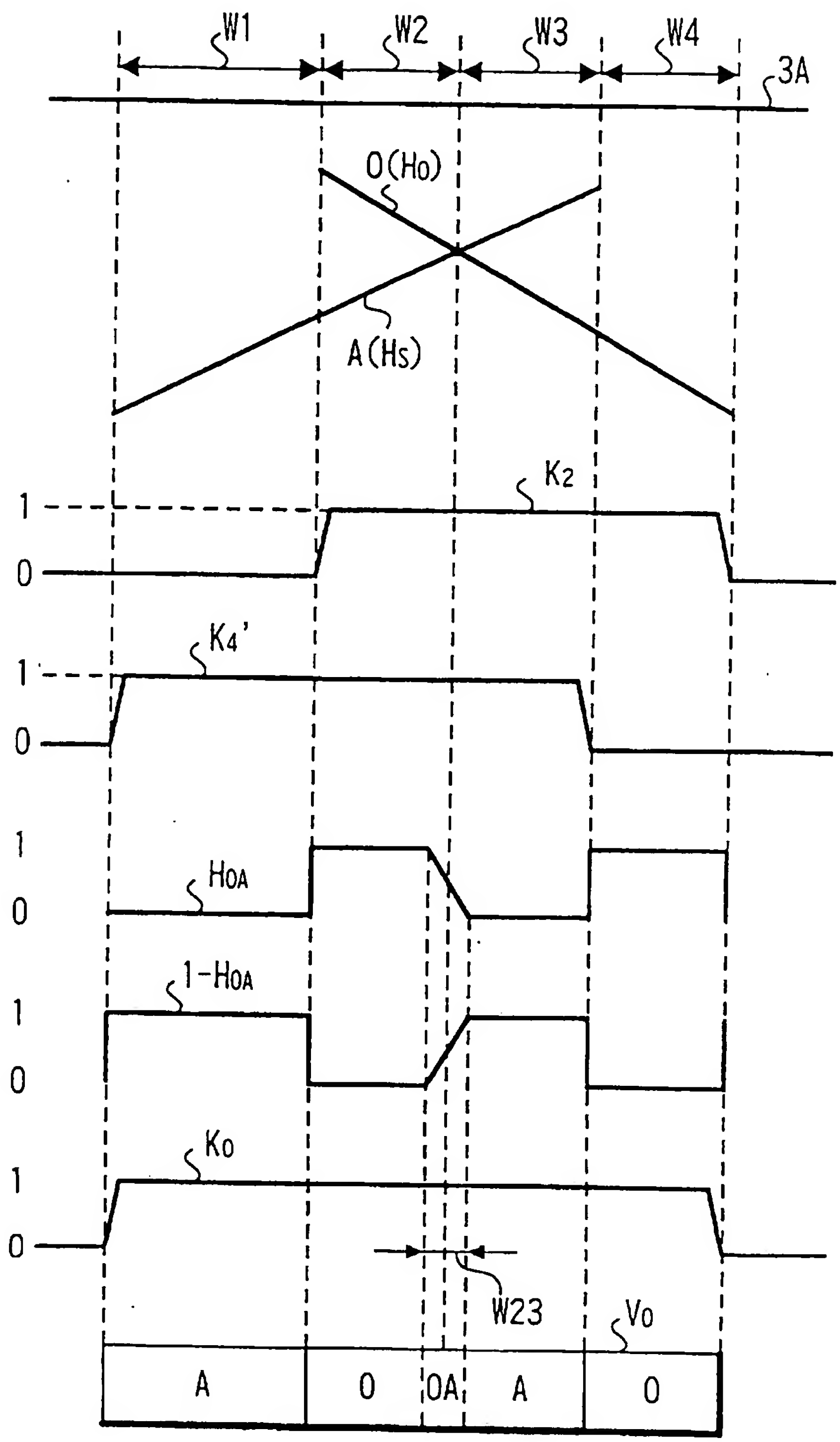


F I G. 19B



F I G. 19C

FIG. 20A
FIG. 20B
FIG. 20C
FIG. 20D
FIG. 20E
FIG. 20F
FIG. 20G



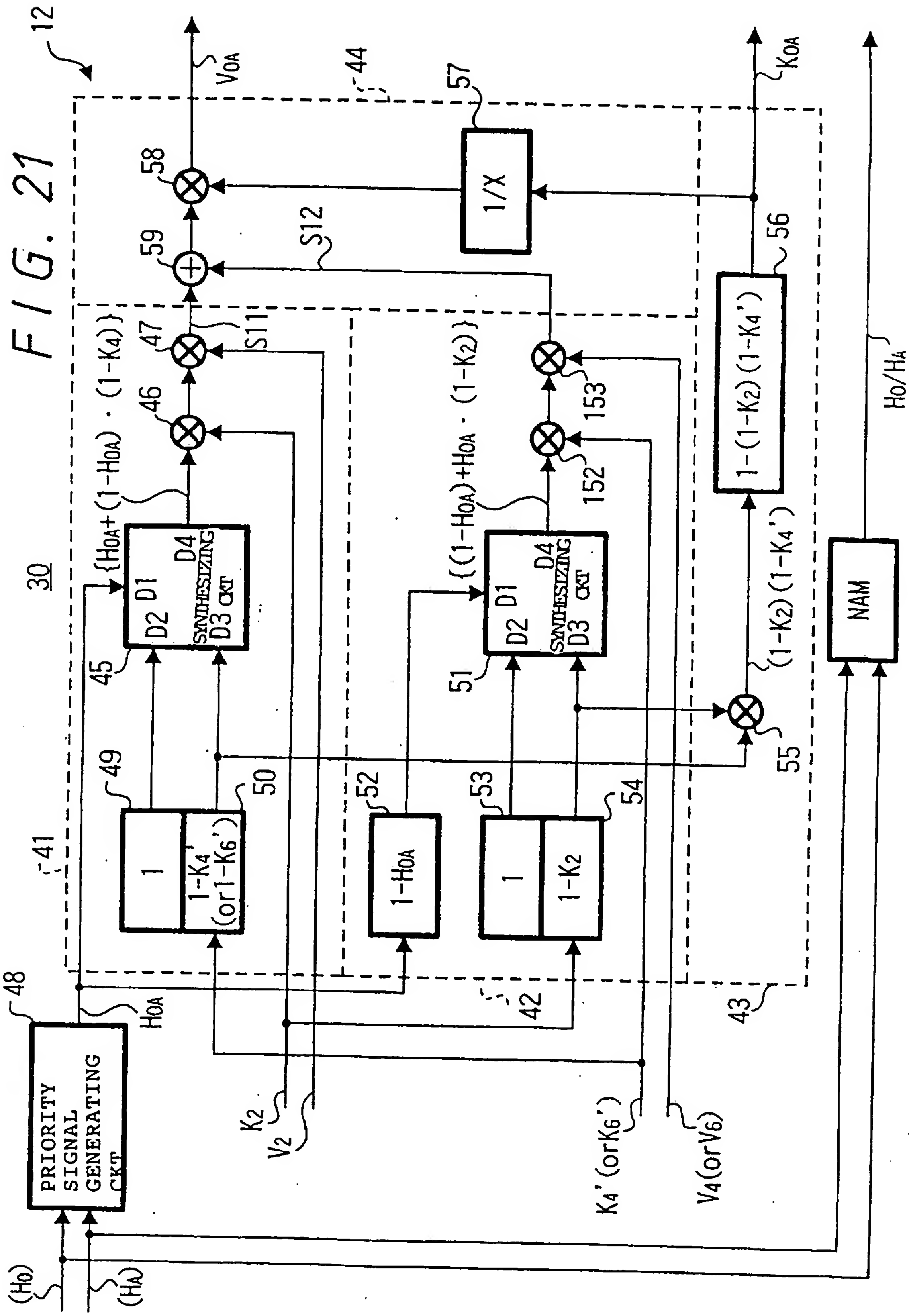
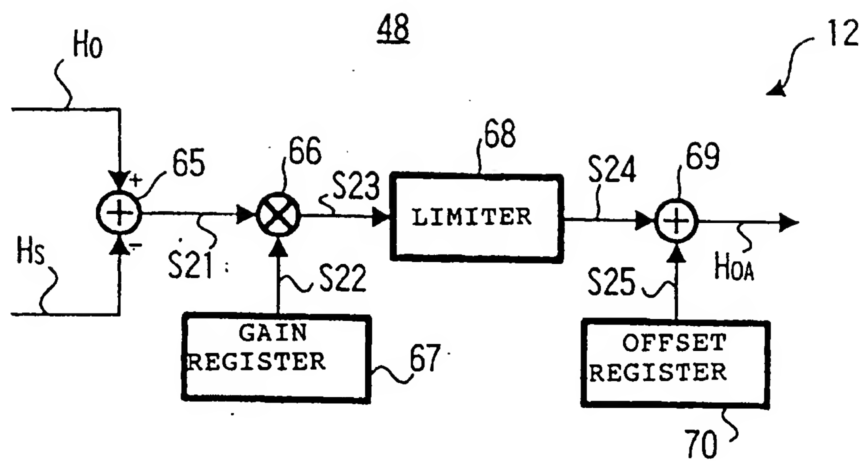

12
30
44
57
58
59
S12
56
47
S11
46
V_{OA}
K_{OA}
1/X
$\{H_{OA}+(1-H_{OA})\cdot(1-K_4)\}$
$\{(1-H_{OA})+H_{OA}\cdot(1-K_2)\}$
153
152
$1-(1-K_2)(1-K_4')$
H_0/H_A
D1
D2
D3
D4
SYNTHESIZING CKT
45
51
NAM
$(1-K_2)(1-K_4')$
55
49
50
41
1
$1-K_4'$ (or $1-K_6'$)
52
$1-H_{OA}$
53
54
$1-K_2$
48
PRIORITY SIGNAL GENERATING CKT
H_{OA}
42
43
K_2
V_2
K_4' (or K_6')
V_4 (or V_6)
(H_0)
(H_A)

FIG. 21

FIG. 22



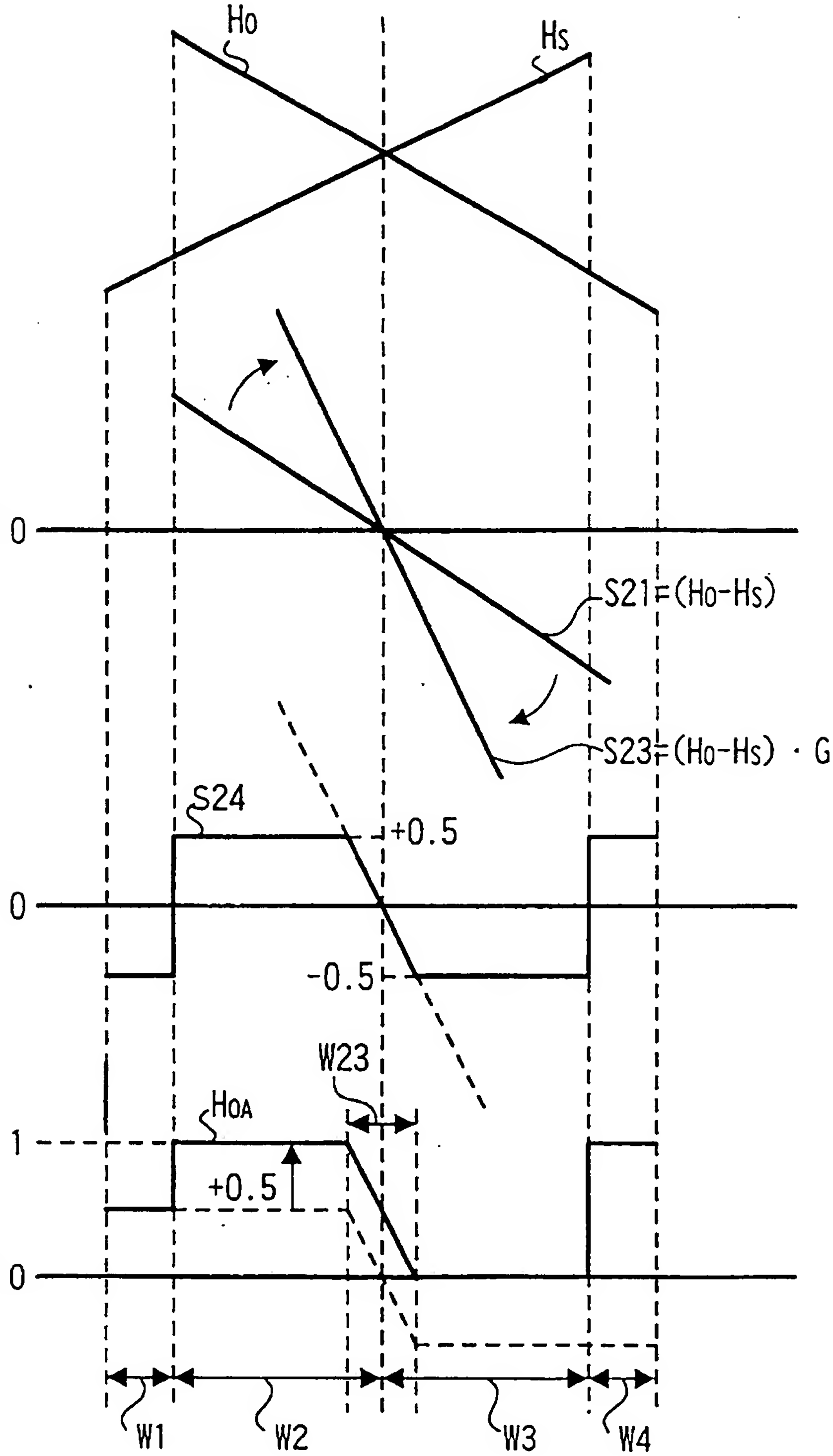
48
12
Ho
Hs
65
+
-
S21
66
S23
S22
68
LIMITER
S24
69
S25
HOA
GAIN REGISTER
67
OFFSET REGISTER
70

FIG. 23A

FIG. 23B

FIG. 23C

FIG. 23D



DESCRIPTION OF REFERENCE NUMERALS

3 ... monitor screen

5 ... control panel

5a ... interface circuit

6 ... ROM

7 ... RAM

8 ... CPU

9 ... screen address generating circuit

10 ... object signal generating unit

12 ... frame memory

13 ... frame memory

14 ... read address generating circuit

20 ... shadow signal generating unit

21 ... color mat generating circuit

22 ... frame memory

23 ... frame memory

24 ... read address generating circuit

30 ... combiner

40 ... mixer

DESCRIPTION

SPECIAL EFFECTS DEVICE AND SPECICAL EFFECTS METHOD

TECHNICAL FIELD

The present invention relates to an image processing device, and particularly to a special effects device capable of obtaining stereoscopic effects by adding a proper shadow signal to an object video signal which was image-transformed in a three-dimensional fashion.

BACKGROUND ART

FIG. 1 shows a video special effects device, for example. FIG. 1A is an explanatory diagram showing one of video special effects devices, and FIG. 1B is a block diagram showing a video special effects device capable of realizing such video special effects.

As shown in FIG. 1A, the video special effects device shown in FIG. 1B generates a pseudo shadow IS from an object O, and synthesizes the object O and the pseudo shadow IS. An object is an image to be processed by special effects, and an object video signal is a video signal to be processed by special effects.

A video special effects device shown in FIG. 1B comprises a mixing circuit 102 for subtracting a key signal K supplied through an input terminal 101 from a background signal BG supplied through an input terminal 103 and adding a video signal Vi supplied through the input terminal 100 to this computed result, a memory 104 for memorizing the key signal K supplied through the input terminal 101, an operation unit 105 for generating a pseudo

shadow signal IS by changing X, Y address directions of the key signal K memorized on this memory 104, an over/under circuit 106 for subtracting an overlapping portion of the pseudo shadow signal IS and the key signal K supplied through the input terminal 101 from the pseudo shadow signal IS stored in the memory 104 and a mixing circuit 107 for subtracting an over/under-processed output K/IS of the over/under circuit 106 from a mixed signal MIX of the mixing circuit 102 and mixing a color mat signal supplied through the input terminal 108 to the subtracted result to thereby output a mixed result from an output terminal 109 as an output signal OUT.

An operation of the video special effects device shown in FIG. 1B will be described with reference to FIG. 1A.

An object video signal Vi is supplied from the input terminal 100. This object video signal corresponds to the object O shown in FIG. 1A. The key signal K supplied from the input terminal 101 is a key signal K for keying the object video signal Vi. The mixing circuit 101 subtracts a signal equivalent to the key signal K from the background signal BG and adds the object video signal Vi to that position to generate the mixed signal MIX.

On the other hand, the key signal K supplied from the input terminal 101 is supplied to the memory 104.

When the X and Y address directions are changed by the operation unit 105, the operation unit 105 changes the position of the key signal K in the memory 104. The key signal K is read out from the memory 104, and supplied to the over/under circuit 106 as the pseudo shadow signal IS. A picture of the pseudo shadow

signal IS becomes an image in which a pseudo shadow I is not hidden by the object O as shown in FIG. 1A. The key signal K and the pseudo shadow signal IS are supplied to the over/under circuit 106. The over/under circuit 106 subtracts the overlapping portion of the key signal and the pseudo shadow signal IS from the pseudo shadow signal IS. The over/under-processed output from the over/under circuit 106 is equivalent to the pseudo shadow IS shown in FIG. 1A.

The over/under-processed output K/IS and the mixed signal MIX are supplied to the mixing circuit 107. The mixing circuit 107 subtracts the over/under-processed output K/IS of the over/under circuit 106 from the mixed signal MIX from the mixing circuit 102, adds the color mat signal supplied through the input terminal 108 to this subtracted result, and outputs this added result from the output terminal 109 as the output signal OUT. This output signal represents the whole of the image shown in FIG. 1A.

The pseudo shadow I shown in FIG. 1A is obtained by simply shifting the key signal generated from the object O, i.e. the pseudo shadow image shown in FIG. 1A is a two-dimensional image. Accordingly, to make the pseudo shadow become closer to a real shadow, a two-dimensional image has to become a three-dimensional image. In this case, a rotated shadow has to be generated for the object and the object and this generated shadow have to be synthesized. To this end, there have to be prepared a video special effects apparatus for object and a video special effects apparatus for shadow, wherein the object and the shadow have to be synthesized

after rotation axes of the object and the shadow had been changed. In this case, a required operation technique becomes highly sophisticated because images generated by the different video special effect apparatus are synthesized.

Further, the contour of the shadow becomes unclear and the color of the shadow becomes light as a distance of a real shadow from an object increases. Accordingly, in order to meet with requirements in which a shadow like a real shadow is added to an image by special effects, it is necessary to execute a processing corresponding to the distance from the object. However, at the present time, it is very difficult to execute such processing by the special effects apparatus. Of course, if a computer graphics technology is used, it is possible to generate an image of a shadow which is very close to the real shadow. However, the computer graphics requires an enormous time to generate one image. Accordingly, it is almost impossible to process images entered incessantly such as broadcasting and authoring by the computer graphics.

DISCLOSURE OF INVENTION

A special effects apparatus according to this invention is a special effects apparatus for effecting a special effects processing on an object represented by a video signal and a shadow of the object, and includes gain control means for controlling a gain of an object shadow image, filtering means for filtering the shadow image, control means for controlling the gain control means in response to depth information of the shadow and controlling a

filter characteristic of the filtering means in response to the depth information of the shadow, and synthesizing means for synthesizing the object shadow image outputted under control of the control means, the object image and a background image of the object.

In the special effects apparatus according to this invention, the control means includes memory means for storing gain characteristic data corresponding to the depth information and filter characteristic data, and the control means controls the gain of the gain control means in response to the gain characteristic data stored in the memory means and the filer characteristic of the filtering means in response to the filter characteristic data stored in the memory means.

In the special effects apparatus according to this invention, the filtering means is comprised of a low-pass filter.

The special effects apparatus according to this invention is a special effects apparatus for effecting a special effects processing on an inputted source video signal, and includes object signal generating means for generating an object signal indicative of a target image by effecting a first image transform processing on the source video signal, shadow signal generating means for generating a shadow signal corresponding to the target image by effecting a second image transform processing on the source video signal and synthesizing means for receiving an object signal outputted from the object signal generating means and the shadow signal outputted from the shadow video signal generating unit and

outputting an output video signal by synthesizing the object signal, the shadow signal and a background signal corresponding to the source video signal and wherein the shadow signal generating means includes gain control means for controlling a gain of the shadow signal corresponding to the source video signal, filter means for filtering the shadow signal, depth information generating means for generating depth information corresponding to the shadow signal and control means for controlling a gain of the gain control means based on depth information from the depth information generating means and controlling a filter characteristic of the filter means based on the depth information.

In the special effects apparatus according to this invention, the shadow signal inputted to the shadow signal generating means is inputted to the gain control means from which it is outputted as a gain-controlled shadow signal and the gain-controlled shadow signal is inputted to the filter means, in which it is filtered and outputted from the filter means as a shadow signal.

In the special effects apparatus according to this invention, the filter means is comprised of a low-pass filter.

In the special effects apparatus according to this invention, the control means includes memory means for storing gain characteristic data corresponding to the depth information from the depth information generating means and filter characteristic data and wherein the gain characteristic data and the filter characteristic data are supplied from the memory means to the gain

control means and the filter means in response to the depth information.

In the special effects apparatus according to this invention, the object signal generating means includes memory means for storing the inputted source video signal and read address generating means for generating a read address such that the source video signal memorized in the memory means is read out at a predetermined unit, and wherein the first image transform processing processes the object video signal read out from the memory means by the read address as a target image.

In the special effects apparatus according to this invention, the shadow video signal generating means includes memory means for storing the inputted source video signal and read address generating means for generating a read address for reading the source video signal memorized in the memory means at a predetermined unit, and wherein the second image transform processing transforms the shadow video signal read out from the memory means by the read address as a shadow signal corresponding to the target image.

In the special effects apparatus according to this invention, the synthesizing means comprises first synthesizing means for receiving the object signal from the object signal generating means and the shadow signal from the shadow signal generating means and outputting a mixed signal synthesizing the respective inputted signals and second synthesizing means for outputting an output video signal by synthesizing the inputted mixed signal and the inputted background signal.

In a special effects apparatus for effecting special effects on an inputted source video signal and a source key signal corresponding to the source video signal, a special effects apparatus according to this invention comprises object signal generating means for effecting a first image transform processing on the inputted source video signal and the inputted source key signal to generate an object video signal indicative of a target image and an object key signal, shadow signal generating means for effecting a second image transform processing on the source video signal and the source key signal to generate a shadow video signal corresponding to the target image and a real shadow key signal and synthesizing means for receiving the object video signal and the object key signal from the object signal generating means, the shadow video signal and the real shadow signal from the shadow signal generating means and a background signal corresponding to the source video signal and synthesizing the above-mentioned respective signals to generate and output an output video signal and wherein the shadow signal generating means includes shadow key signal generating means for generating a shadow key signal corresponding to the target image for the inputted source key signal, gain control means for controlling a gain of a shadow signal outputted from the shadow key signal generating means, filtering means for filtering the shadow key signal, depth information generating means for generating depth information corresponding to the shadow signal and control means for controlling a gain of the gain control means based on the depth information from the depth information generating

means and controlling a filter characteristic of the filtering means based on the depth information.

In the special effects apparatus according to this invention, the filtering means is comprised of a low-pass filter.

In the special effects apparatus according to this invention, the shadow signal outputted from the shadow key signal generating means of the shadow signal generating means is outputted as a shadow signal whose gain was controlled by the gain control means, and the gain-controlled shadow signal is inputted to the filtering means, in which it is controlled in filter characteristic and outputted as a real shadow key signal.

In the special effects apparatus according to this invention, the control means in the shadow signal generating unit includes memory means in which gain characteristic data corresponding to the depth information from the depth information generating means and filter characteristic data are memorized and the gain characteristic data and the filter characteristic data are respectively supplied to the gain control means and the filtering means in response to the depth information.

In the special effects apparatus according to this invention, the synthesizing means includes first synthesizing means for receiving the object video signal and the object key signal from the object signal generating means and the shadow video signal and the real shadow key signal from the shadow signal generating means and synthesizing the respective signals to generate a mixed video signal and a mixed key signal and second synthesizing means

for synthesizing the mixed video signal and the mixed key signal from the first synthesizing means and the background signal to generate the output video signal.

In the special effects apparatus according to this invention, the object signal generating means includes first memory means for memorizing the source video signal, second memory means for memorizing the source key signal and read address generating means for generating a read address used to read the source video signal and the source key signal memorized in the first memory means and the second memory means from the respective memory means and supplying the read address to the first memory means and the second memory means and wherein the first image transform processing outputs the object video signal and the object key signal read out from the first memory means and the second memory means by the read address as the target image.

In the special effects apparatus according to this invention, the shadow signal generating means includes third memory means for memorizing the source video signal, fourth memory means for memorizing the source key signal and read address generating means for generating a read address used to read out the source video signal and the source key signal memorized in the third memory means and the fourth memory means from the respective memory means and supplying the read address to the third memory means and the fourth memory means and wherein the second image transform processing outputs the shadow video signal and the shadow key signal read out from the third memory means and the fourth memory means

by the read address and outputs the shadow video signal as a shadow video signal corresponding to the target image.

In a special effects method for effecting a special effects processing on an object indicated by an inputted video signal and a shadow relative to the object, a special effects method according to this invention comprises a gain step for controlling a gain of an image indicative of a shadow of the object, a filter step for filtering an image of the shadow, a control step of controlling a gain of the gain step in response to depth information of the shadow and controlling a filter characteristic of the filter step in response to the shadow depth information and a synthesizing step of synthesizing the object image and an image which becomes a background of the object to output an output video signal.

In the special effects method according to this invention, the control step controls the gain step to control the gain by gain characteristic data corresponding to the depth information memorized in memory means and controls the filter step to filter the shadow image by filter characteristic data corresponding to the depth information memorized in the memory means.

In a special effects method of effecting a special effects processing on an inputted source video signal, a special effects method according to this invention comprises an object signal generating step of effecting a first image transform processing on the source video signal to generate an object signal indicative of a target image, a shadow signal generating step of

effecting a second image transform processing on the source video signal to generate a shadow signal corresponding to the target image and a synthesizing step of receiving the object signal, the shadow signal and a background signal corresponding to the source video signal and synthesizing the above-mentioned respective signals to output an output video signal, and the shadow signal step includes a gain control step of controlling a gain of the shadow signal corresponding to the source video signal, a filter step of filtering the shadow signal, a depth information generating step of generating depth information corresponding to the shadow signal and a control step of controlling a gain of the gain control step based on the depth information from the depth information generating step and controlling a filter characteristic of the filter step based on the depth information.

In a special effects method comprising an object signal generating step of effecting a first image transform processing on an inputted source video signal to generate an object signal indicative of a target image, a shadow signal generating step of effecting a second image transform processing on the source video signal to generate a shadow signal corresponding to the target image and a synthesizing step of receiving the object signal generated by the object signal generating step and the shadow signal generated by the shadow video signal generating step and synthesizing the object signal, the shadow signal and a background signal corresponding to the source video signal to output an output video signal, and the shadow signal generating step includes a gain

control step of controlling a gain of the shadow signal corresponding to the source video signal, a filter step of filtering the shadow signal, a depth information generating step of generating depth information corresponding to the shadow signal and a control step of controlling a gain of the gain control step based on the depth information from the depth information generating step and controlling a filter characteristic of the filter step, according to the present invention, there is provided a special effects method in which the filter step is executed by a low-pass filter.

In the special effects method according to this invention, the control step includes a memory step for memorizing gain characteristic data and filter characteristic data corresponding to the depth information from the depth information generating step and supplies the gain characteristic data and the filter characteristic data from the memory step to the gain control step and the filter step in response to the depth information.

In the special effects method according to this invention, the object signal generating step includes a memory step for memorizing the inputted source video signal and a read address generating step for generating a read address so that the source video signal memorized at the memory step is read out at a predetermined unit, and the first image transform processing processes the object video signal read out from the memory step by the read address as a target image.

In the special effects method according to this invention, the shadow video signal generating step includes a memory

step for memorizing the inputted source video signal and a read address generating step for generating a read address so that the source video signal memorized at the memory step is read out at a predetermined unit, and the second image transform processing processes the shadow video signal read out from the memory step by the read address as a shadow signal corresponding to the target image.

In the special effects method according to this invention, the synthesizing step includes a first synthesizing step for receiving the object signal from the object signal generating step and the shadow signal from the shadow signal generating step and synthesizing the above-mentioned respective signals to output a mixed signal and a second synthesizing step for synthesizing the mixed signal and the background signal to output an output video signal.

In a special effects method of effecting a special effects processing on an inputted source video signal and a source key signal corresponding to the source video signal, a special effects method according to this invention comprises an object signal generating step for effecting a first image transform processing on the inputted source video signal and the inputted source key signal to generate an object video signal and an object key signal indicative of a target image, a shadow signal generating step for effecting a second image transform processing on the inputted source video signal and the inputted source key signal to generate a shadow video signal and a real shadow signal

corresponding to the target image and a synthesizing step for receiving the object video signal and the object key signal outputted from the object signal generating step, the shadow video signal and the real shadow key signal from the shadow signal generating step and a background signal corresponding to the source video signal and synthesizing the above-mentioned inputted respective signals to generate and output an output video signal and wherein the shadow signal generating step includes a shadow key signal generating step for generating a shadow key signal corresponding to the target image for the inputted source key signal, a gain control step for controlling a gain of the shadow key signal outputted from the shadow key signal generating step, a filter step for filtering the shadow key signal, a depth information generating step for generating depth information corresponding to the shadow signal and a control step for controlling a gain of the gain control step and controlling a filter characteristic of the filter step based on the depth information.

In the special effects method according to this invention, the filter step is executed by a low-pass filter.

In the special effects method according to this invention, the shadow key signal outputted from the shadow key signal generating step of the shadow signal generating step is outputted as the shadow key signal whose gain was controlled a the gain control step and the shadow key signal whose gain was controlled is inputted to the filter step, in which it is controlled in filter characteristic and outputted as a real shadow key.

In the special effects method according to this invention, the control step of the shadow signal generating step includes a memory step for memorizing gain control data corresponding to the depth information from said depth information generating step and filter characteristic data and wherein said gain characteristic data and said filter characteristic data are supplied to said gain control step and said filter step in response to said depth information.

In the special effects method according to this invention, said synthesizing step includes a first synthesizing step for receiving the object video signal and the object key signal from the object signal generating step and the shadow video signal and the real shadow key signal from the shadow signal generating step and synthesizing the respective inputted signals to generate a mixed video signal and a mixed key signal and a second synthesizing step for receiving the mixed video signal and the mixed key signal from the first synthesizing step and the background signal to generate the output video signal.

In the special effects method according to this invention, the object signal generating step includes a first memory step for memorizing the source video signal, a second memory step for memorizing the source key signal and a read address generating step for generating a read address to read out the source video signal and the source key signal from the first memory step and the second memory step and supply a read address to the first memory step and the second memory step, and the first image transform

processing outputs the object video signal and the object key signal read out from the first memory step and the second memory step by the read address as a target image.

In the special effects method according to this invention, the shadow signal generating step include a third memory step for memorizing the source video signal, a fourth memory step for memorizing the source key signal and a read address generating step for generating a read address to read out the source video signal and the source key signal memorized in the third memory step and the fourth memory step from the respective memory steps and supplying the read address to the third memory step and the fourth memory step and the second image transform processing executes a processing such that the shadow video signal and the shadow key signal read out from the third memory step and the fourth memory step by the read address are outputted and the shadow video signal is outputted as a shadow video signal corresponding to said target image.

The present invention includes a shadow generating means for generating a shadow image, a synthesizing means for synthesizing an object image to be shadowed, the shadow image and a background image, a memory means for memorizing gain characteristic data corresponding to the ratio x/y and filter characteristic data, a gain control means for controlling a gain of the shadow image, a filter means for filtering the shadow image, and a control means for calculating a ratio x/y of a distance x between the shadow image and the object image and a distance y

between a virtual light source and the object image, controlling a gain in the gain control means in response to the gain characteristic corresponding to the ratio x/y and controlling a filter characteristic in the filter means in response to the filter characteristic corresponding to the ratio x/y.

The gain in the gain control means is controlled in response to a gain characteristic corresponding to the ratio x/y, the filter characteristic in the filter means is controlled in response to a filter characteristic corresponding to the ratio x/y, a shadow image closer to a real shadow is generated, and the shadow image, the object image and the background image are synthesized.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a diagram used to explain the background art;

FIG. 2 is a block diagram showing an overall arrangement of a special effects apparatus according to the present invention;

FIG. 3 is a diagram used to explain a world coordinates system defined in the special effects apparatus according to the present invention;

FIG. 4 is a diagram used to explain a transform processing for obtaining an object video signal;

FIG. 5 is a diagram showing a relationship between an address on a frame memory corresponding to an object video signal and an address on a monitor screen;

FIG. 6 is a diagram showing the manner in which pixel data are arrayed on a monitor screen surface for indicating a meaning of a parameter H and a frame memory;

FIG. 7 is a diagram showing an address space of a frame memory obtained when a perspective is used;

FIG. 8 is a conceptual diagram showing a relationship between a world coordinate system and a shadow coordinate system;

FIG. 9 is a diagram used to explain a transform processing for obtaining a shadow video signal in a point source mode and a diagram showing a relationship between an address on a frame memory corresponding to the shadow video signal and an address on a monitor screen surface;

FIG. 10 is a diagram used to explain a perspective transform processing for obtaining a three-dimensional shadow video signal from a three-dimensional object video signal in a point source mode;

FIG. 11 is a flowchart showing the procedure of the transform processing for obtaining a point source and a three-dimensional object video signal;

FIG. 12 is a diagram used to explain a transform processing for obtaining a shadow video signal in a parallel light source mode;

FIG. 13 is a flowchart showing the procedure of a transform processing for the parallel light source and the three-dimensional object video signal;

FIG. 14 is a diagram showing a relationship between spherical coordinates and orthogonal coordinates in a world coordinates system and a shadow coordinates system;

FIG. 15 is a diagram used to explain a perspective

transform processing for obtaining a three-dimensional shadow video signal from a three-dimensional object video signal in a parallel light source mode;

FIG. 16 is a diagram used to explain a perspective transform processing for obtaining a virtual three-dimensional shadow video signal from a virtual three-dimensional object video signal;

FIG. 17 is a diagram used to explain an origin setting mode for automatically setting an origin of shadow coordinates system;

FIG. 18 is a block diagram showing a real shadow generator;

FIG. 19 is a diagram showing a target image and a diagram showing a relationship among a parameter H and gain and filter characteristics;

FIG. 20 is a diagram used to explain the manner in which two crossing images are synthesized;

FIG. 21 is a block diagram showing a combiner in detail;

FIG. 22 is a block diagram showing a priority signal generating circuit in FIG. 21 in detail;

FIG. 23 is a signal waveform diagram useful for explaining an operation of a priority signal generating circuit in FIG. 22.

BEST MODE FOR CARRYING OUT THE INVENTION

(1) OVERALL ARRANGEMENT

Initially, a special effects apparatus 1 according to

the present invention 1 will be described with reference to FIG. 2.

A CPU 8 is a processor for controlling all circuits of this special effects apparatus 1. The CPU 8 receives respective parameters, obtained when an operator operates a control panel 5, through an interface circuit (I/F) 5a and a data bus, and controls respective circuit based on the resultant parameters. From this control panel 5, the operator enters a perspective value Pz, rotation angles (θ_x, θ_y, θ_z) of Xs axis, Ys axis and Zs axis of a shadow coordinates system, origins (x_{s0}, y_{s0}, z_{s0}) of the shadow coordinates system, the kind of light source for indicating whether a light source is a parallel light source or a point source, a point source position (x_L, y_L, Z_L), a parallel light source position (γ, α, β) and parameters γ_{11} to γ_{33}, l_x, l_y, l_z and s concerning a three-dimensional transform. Incidentally, the respective parameters will be described later on. Also, the CPU 8 receives these parameters entered from the control panel 5, read out these parameters in real time, and reflects these parameters on the computation of the read address. Specifically, the CPU 8 monitors the change of the parameter supplied from the control panel 5 at a frame period, and computes parameters (b_{11} to b_{33}, b_{11}' to b_{33}', b_{11}'' to b_{33}'') used to compute the read address based on the parameter supplied thereto at a frame period. Thus, these parameters may be varied in real time at the frame period in response to the operation of the operator, and the special effects may be effected on the source video signal in real time in response to the varied

parameters.

Incidentally, the special effects apparatus according to this invention is able to select a desired light from the point source and the parallel light source by entering the kind of the light source from the control panel 5. In the description which follows, a mode for generating an object shadow by a point source will be referred to as a point source mode, and a mode for generating an object shadow by a parallel light source will be referred to as a parallel light source mode.

Also, the CPU 8 controls respective circuits based on a program memorized in a ROM (Read Only Memory) provided as a program memory, and computes a read address. Also, similarly, the central processing unit controls respective circuits based on data memorized in a RAM (Random Access Memory) 7 provided as a work memory, and computes a read address.

The object signal generating unit 10 receives a source video signal V_0 from the outside, and generates a two-dimensional object video signal V_3 by effect a three-dimensional transform processing on this source video signal V_0. Also, the object signal generating unit 10 receives a source key signal K_0 for keying the source video signal V_0, and generates an object key signal K_2 by effecting a three-dimensional transform processing on the source key signal K_0 similarly to the source video signal. Specifically, this object signal generating unit 10 includes a frame memory 12 for temporarily memorizing the source video signal V_0, a frame memory 13 for temporarily memorizing the source key signal K_0 for keying

the source video signal and a read address generating circuit 14 for supplying a read address (X_M, Y_M), computed in response to the three-dimensional transform operation, to the frame memories 12 and 13.

The frame memory 12 is the memory for temporarily memorizing the source video signal V_0 supplied thereto. Since a sequential write address is supplied to this frame memory 12 from a write address generating circuit not shown, the source video signal V_0 supplied thereto is memorized in this frame memory 12 without being transformed. Also, since the read address (X_M, Y_M) computed in response to the three-dimensional transform operation is supplied to this frame memory 12 from the read address generating circuit 14, the frame memory 12 outputs an object video signal V_2 which was processed in a three-dimensional transform manner at every frame. The outputted object video signal V_2 is transmitted to a mixer 30.

The frame memory 13 is a memory for temporarily memorizing the source key signal K_0 for keying the source video signal V_0. Since a write address similar to the sequential write address supplied to the frame memory 12 is supplied to the frame memory 13, similarly to the source video signal V_0, the supplied source key signal K_0 is memorized in this frame memory 13 without being transformed. Also, since the same address (X_M, Y_M) as the read address supplied to the frame memory 12 is supplied to the frame memory 13, the frame memory 13 outputs a three-dimensional-transformed object key signal K_2 similarly to the

three-dimensional-transformed object video signal V_2. The outputted object key signal K_2 is transmitted to a combiner 30.

The read address generating circuit 14 generates the read address (X_M, Y_M), supplied to the frame memories 12 and 13, on the basis of an address (X_s, Y_s) supplied sequentially from the screen address generating circuit 9 to the monitor screen 3 and parameters b_{11} to b_{33} of an image transform matrix computed by the CPU 8.

The concrete computation executed within this read address generating circuit 14 will be described later on.

The arrangement of the object signal generating unit 10 has been described so far. The arrangement of the shadow signal generating unit 20 will be described next.

The shadow signal generating unit 20 is the circuit for generating the shadow video signal and the shadow key signal. Initially, when the point source mode is selected, this shadow signal generating unit 20 receives the source video signal V_0 from the outside, and generates a shadow video signal V_4 by effecting a three-dimensional transform processing on a source video signal which was mat-processed to a color of shadow. Also, the shadow signal generating unit 20 receives the source key signal K_0 for keying the source video signal, and generates a shadow key signal K_4 by effecting a three-dimensional processing on the source key signal similarly to the shadow video signal V_4. When the parallel light source mode is selected, this shadow signal generating unit 20 receives the source video signal V_0 supplied from the outside,

three-dimensional-transformed object video signal V_2. The outputted object key signal K_2 is transmitted to a combiner 30.

The read address generating circuit 14 generates the read address (X_M, Y_M), supplied to the frame memories 12 and 13, on the basis of an address (X_s, Y_s) supplied sequentially from the screen address generating circuit 9 to the monitor screen 3 and parameters b_{11} to b_{33} of an image transform matrix computed by the CPU 8.

The concrete computation executed within this read address generating circuit 14 will be described later on.

The arrangement of the object signal generating unit 10 has been described so far. The arrangement of the shadow signal generating unit 20 will be described next.

The shadow signal generating unit 20 is the circuit for generating the shadow video signal and the shadow key signal. Initially, when the point source mode is selected, this shadow signal generating unit 20 receives the source video signal V_0 from the outside, and generates a shadow video signal V_4 by effecting a three-dimensional transform processing on a source video signal which was mat-processed to a color of shadow. Also, the shadow signal generating unit 20 receives the source key signal K_0 for keying the source video signal, and generates a shadow key signal K_4 by effecting a three-dimensional processing on the source key signal similarly to the shadow video signal V_4. When the parallel light source mode is selected, this shadow signal generating unit 20 receives the source video signal V_0 supplied from the outside,

and generates a shadow video signal V_6 by effecting a three-dimensional transform processing on a source video signal which was mat-processed to a color of shadow. Also, Also, the shadow signal generating unit 20 receives the source key signal for keying the source video signal, and generates a shadow key signal K_6 by effecting a three-dimensional transform processing on the source key signal similarly to the shadow video signal V_6. Specifically, this shadow signal generating unit 20 has a circuit arrangement similar to that of the object signal generating unit 10, and includes a color mat generating circuit 21 for mat-processing the source video signal V_0, a frame memory 22 for temporarily memorizing the mat-processed source video signal, a frame memory 23 for temporarily memorizing the source key signal K_0 and a read address generating circuit 24 for supplying a computed read address to the frame memories 22 and 23.

The color mat generating circuit 21 is the circuit for making the color of the source video signal V_0 become close to a color of shadow by mat-processing the source video signal V_0. In the simplest example, the color of the source video signal becomes close to a color (black) of shadow by lowering saturation and brightness levels of the source video signal V_0.

The frame memory 22 is the memory for temporarily memorizing the mat-processed source video signal. Since a sequential write address is supplied to this frame memory 22 from a write address generating circuit not shown, the mat-processed source video signal is memorized in this frame memory 22 without

being image-transformed. In the point source mode, since a read address (X_M', Y_M') computed based on the three-dimensional transform operation and the point source is supplied to this frame memory 22 from the read address generating circuit 24, this frame memory 22 outputs the three-dimensional-transformed shadow video signal V_4. In the parallel light source mode, since a read address (X_M'', Y_M'') computed based on the three-dimensional transform operation and the parallel light source is supplied to this frame memory 22 from the read address generating circuit 24, this frame memory 22 outputs a three-dimensional-transformed shadow video signal V_6.

The frame memory 23 is the memory for temporarily memorizing the source key signal K_0 for keying the source video signal V_0. Since the same address as the sequential write address supplied to the frame memory 22 is supplied to this frame memory 23, the supplied source key signal K_0 is memorized in this frame memory 23 without being image-transformed. In the point source mode, since the same address (X_M', Y_M') as the read address supplied to the frame memory 22 is supplied to the frame memory 23, this frame memory 23 outputs a shadow key signal K_4 which is three-dimensional-transformed similarly to the three-dimensional-transformed shadow video signal V_4. In the parallel light source mode, since the same address (X_M'', Y_M'') as the read address supplied to the frame memory 22 is supplied to the frame memory 23, this frame memory 23 outputs a shadow key signal K_6 which is three-dimensional-transformed similarly to the three-dimensional-transformed shadow video signal V_6.

The read address generating circuit 24 is the circuit for generating the read address supplied to the frame memories 22 and 23. In the point source mode, the read address generating circuit generates a read address (X_M', Y_M') on the basis of the address (X_s, Y_s) sequentially supplied from the screen address generating circuit 9 to the monitor screen 3 and the parameters b_{11}' to b_{33}' of the image transform matrix computed by the CPU 8. In the parallel light source mode, the read address generating circuit generates a read address (X_M'', Y_M'') on the basis of the address (X_s, Y_s) sequentially supplied from the screen address generating circuit 9 to the monitor screen 3 and the parameters b_{11}'' to b_{33}'' of the image transform matrix computed by the CPU 8. A concrete computation executed within this read address generating circuit 24 will be described later on.

A real shadow signal generator 50 receives the shadow key signal (K_4 in the point source mode and K_6 in the parallel light source mode) outputted from the frame memory 23, and outputs a real shadow key signal (K_4' in the point source mode and K_6' in the parallel light source mode), which is used to generate a more realistic shadow, relative to this inputted shadow signal. The details of this real shadow signal generator 50 will be described later on.

The arrangement of the shadow video signal generating unit 20 has been described so far.

The screen address generating circuit 9 is the circuit for addressing the whole screen surface of the monitor screen 3 in the order corresponding to the order of the raster scanning.

Specifically, the screen address generating circuit 9 generates a screen address (X_s, Y_s) based on a horizontal synchronizing signal and a vertical synchronizing signal generated in the inside.

The combiner 30 is the circuit for mixing the signals from the object signal generating unit 10 and the shadow signal generating unit 20. In the point source mode, the combiner 30 receives the object video signal V_3 and the object key signal K_3 outputted from the object signal generating unit 10 and the shadow video signal V_4 and the real shadow key signal K'_4 outputted from the shadow signal generating unit 20, and generates a mixed key signal K_{MIX}' by mixing a mixed video signal V_{MIX}' which results from mixing the object video signal V_2 and the shadow video signal V_4 and a mixed key signal K_{MIX}' which results from mixing the object key signal K_2 and the real shadow key signal K_4'. To be concrete, the mixed video signal V_{MIX}' and the mixed key signal K_{MIX}' may be expressed by the following equation:

$$V_{MIX}' = K_2V_2 + (1 - K_s)\ K'_4V_4$$
$$K_{MIX}' = 1 - (1 - K_2)\ (1 - K'_4) \qquad \ldots \text{(a)}$$

Also, in the parallel light source mode, the combiner receives the object video signal V_2 and the object key signal K_2 outputted from the object signal generating unit 10 and the shadow video signal V_6 and the real shadow key signal K'_6 outputted from the shadow signal generating unit 20, and generates a mixed video signal V_{MIX}'' which results from mixing the object video signal V_2 and the shadow video signal V_6 and a mixed key signal K_{MIX}'' which results from mixing the object key signal K_2 and the real shadow key signal K'_6. To be

concrete, the mixed video signal V_{MIX}'' and the mixed key signal K_{MIX}'' may be expressed by the following equation:

$$V_{MIX}'' = K_2 V_2 + (1 - K_2)\ K'_6\ V_6$$

$$K_{MIX}'' = 1 - (1 - K_2)\ (1 - K'_6) \qquad \ldots \text{(b)}$$

The details of the combiner 30 will be described later on.

A mixer 40 is a circuit for mixing the mixed video signal and the mixed key signal outputted from the combiner 30 and a background video signal V_{BK} supplied from the outside. In the point source mode, this mixer receives the mixed video signal V_{MIX}' and the mixed key signal K_{MIX}' outputted from the mixer 30 and the background video signal V_{BK} supplied from the outside, and generates an output video signal V_{OUT}' by mixing the mixed video signal V_{MIX}' and the background video signal V_{BK}. To be concrete, this output video signal V_{OUT}' may be expressed by the following equation:

$$V_{OUT}' = K_{MIX}'\ V_{MIX}' + (1 - K_{MIX}')\ V_{BK} \qquad \ldots \text{(c)}$$

In the point source mode, this mixer receives the mixed video signal V_{MIX}'' and the mixed key signal K_{MIX}'' outputted from the mixer 30 and the background video signal V_{BK} supplied from the outside, and generates an output video signal V_{OUT}'' by mixing the mixed video signal V_{MIX}'' and the background video signal V_{BK} on the basis of the mixed key signal K_{MIX}''. To be concrete, this output video signal V_{OUT}'' may be expressed by the following equation:

$$V_{OUT}'' = K_{MIX}''\ V_{MIX}'' + (1 - K_{MIX}'')\ V_{BK} \qquad \ldots \text{(d)}$$

The thus generated output video signal V_{OUT}' or V_{OUT}'' is outputted to the outside and is also displayed on the monitor screen 3.

(2) DEFINITION OF WORLD COORDINATES SYSTEM

Initially, a world coordinates system used in the description of the present invention will be described with reference to FIG. 3. This world coordinates system is a three-dimensional orthogonal coordinates system comprising X, Y and Z axes. That is, as shown in FIG. 3, assuming that the screen surface 3 exists on an XY plane defined by the X axis and the Y axis perpendicular to this axis, then the X axis is defined in the horizontal (left and right) direction of the screen surface 3 and the Y axis is defined in the vertical (upper and lower) direction of the screen surface 3.

Also, the depth direction of the screen surface 3 is defined in the positive direction of the Z axis perpendicular to the XY plane, and the front side of the screen surface 3, i.e. side in which a viewpoint PZ for viewing the screen surface exists is defined as the negative direction of the Z axis.

Further, it is defined that the center of the screen surface 3 agrees with an origin of the world coordinates system comprising the X axis, the Y axis and the Z axis.

Consecutive virtual coordinates values are set on the X axis from the inside (origin) of the screen region to the left and right outside directions, and virtual coordinates values of "-4" to "+4" from left to right are set on the X axis within the screen region when the screen surface 3 is seen at the viewpoint PZ.

Consecutive virtual coordinates values are set on the Y axis from the inside (origin) of the screen region to the upper

and lower outside directions, and virtual coordinates values of "-3" to "+3" from lower to upper are set on the Y axis within the screen region when the screen surface 3 is seen at the viewpoint PZ.

Further, the viewpoint position PZ of the operator is virtually set on the Z axis at the position in which its coordinates value becomes "-16".

(3) DESCRIPTION OF TRANSFORM PROCESSING FOR GENERATING THE OBJECT VIDEO SIGNAL:

Initially, with reference to FIGS. 4A and 4B, there will be described a transform processing for generating the object video signal V_2 from the source video signal V_0.

Initially, the source video signal V_0 of two-dimensional data is not image-transformed, and is memorized in the frame memory 12 as it is. Accordingly, as shown in FIGS. 4A and 4B, since the source video signal V_0 exists on the XY plane of the world coordinates system, an image of the source video signal V_0 is displayed on the screen surface 8 which exists on the XY plane.

In this connection, FIG. 4A shows the state in which the XY plane is seen from the viewpoint PZ on the Z axis in the space expressed by three-dimensional coordinates of the world coordinates system, in other words, an image displayed on the screen surface 3. Also, FIG. 4B shows the state in which the XZ plane is seen from the viewpoint position on the positive side of the Y axis in the space expressed by three-dimensional coordinates of the world coordinates system. Therefore, the source video signal V_0 existing

on the XY plane overlaps with the screen surface 3.

When the operator operates control elements on the control panel, the three-dimensional image transform processing in the world coordinates space is effected on such source video signal V_0. That is, the source video signal V_0 is transformed into a three-dimensional spatial position by effecting a three-dimensional transform matrix T_0 composed of parameters set at every frame on each pixel of the source video signal V_0 according to the operation of the operator. In FIG. 4B, the video signal thus three-dimensional-image-transform-processed is expressed as a three-dimensional object video signal V_1. The three-dimensional transform in the case of FIGS. 4A and 4B shows an example in which the source video signal V_0 is rotated about the X axis by about 45° and further moved parallelly in the positive direction of the Z axis.

The three-dimensional transform matrix T_0 used in the three-dimensional transform is expressed by the following equation:

$$T_0 = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & 0 \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & 0 \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & 0 \\ 1_X & 1_Y & 1_Z & s \end{bmatrix} \qquad \cdots (1)$$

The transform parameters γ_{11} to γ_{33} used in this three-dimensional transform matrix T_0 are parameters containing elements for rotating the source video signal V_0 around the X axis, the Y axis and the X axis, elements for enlarging/reducing the scale of the source

video signal V_0 in the X axis direction, the Y axis direction and the Z-axis direction, elements for skewing the source video signal V_0 in the X axis direction, the Y axis direction and the Z axis direction and the like. The parameters l_x, l_y, l_z are parameters containing elements for parallelly moving the source video signal in the X axis direction, the Y axis direction and the Z axis direction. The parameter s is the parameter containing elements for uniformly enlarging/reducing the whole of the source video signal V_0 in the respective axis directions of the three-dimension.

Incidentally, since this transform matrix T_0 expresses the coordinates system such as rotation transform and the coordinates system for parallel movement transform and enlarge reduction transform in the same coordinates system, it becomes a matrix of 4 rows and 4 columns, and is referred to as "homogeneous coordinate" (Homogeneous Coordinate).

As described above, after the source video signal V_0 existing on the XY plane is transformed by the three-dimensional transform matrix T_0 into the three-dimensional position indicated by the three-dimensional object video signal V_1, control goes to the next perspective transform processing.

This perspective transform processing is, as shown in FIGS. 4A and 4B, is the transform processing for projecting the three-dimensional object video signal V_1 on the XY plane by the perspective transform matrix P_0. In other words, the perspective transform is to obtain an image of a video signal projected onto the XY plane when the three-dimensional object video signal V_1 is

seen from the virtual viewpoint PZ on the Z axis. In FIG. 4B, the video signal projected onto the XY plane as described above is expressed as a two-dimensional object video signal V_2. In the case of FIG. 4B, the object video signal V_2 projected onto the screen 3 on the XY plane is a video image obtained as if the three-dimensional object video signal V_1 were existing on the depth side of the screen 3 as seen from the virtual viewpoint PZ.

This perspective transform matrix P_0 is expressed by the following equation:

$$P_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \cdots (2)$$

The parameter P_z of this perspective transform matrix P_0 is a perspective value for the application of the perspective when the three-dimensional transform video signal V_2 is projected onto the XY plane. That is, in the case of FIG. 4B, the three-dimensional object video signal V_1 in the three-dimensional space is inclined by about 45° relative to the XY plane. When this three-dimensional object video signal is seen from the XY plane, the portion distant from the virtual viewpoint PZ is seen small, and the portion close to the virtual viewpoint is seen large. Accordingly, by using the parameter P_z indicating the perspective, the two-dimensional object video signal V_2 projected onto the XY plane is obtained by transforming the three-dimensional object video signal V_1 in the three-dimensional space in response to the distance from the virtual viewpoint PZ.

The position at which the three-dimensional object video signal V_1 is projected onto the screen surface 3 by the perspective transform is changed in response to a distance between the virtual viewpoint PZ and the screen surface 3 and a distance between the virtual viewpoint PZ and the three-dimensional object video signal V_1. If the operator sets the perspective value P_z in response to the position of the virtual viewpoint PZ, it is possible to execute the perspective transform corresponding to the position of the virtual viewpoint PZ. In general, since the position of the viewpoint PZ is a coordinate value "-16" of the z axis, the perspective value P_z is set in such a manner that "1/16" becomes a standard value.

As described above, the transform processing for generating the two-dimensional object video signal V_2 from the source video signal V_0 comprises a spatial image transform step for obtaining the three-dimensional object video signal V_1 from the source video signal V_0 by the three-dimensional transform matrix T_0 and the perspective transform step for transforming the three-dimensional object video signal V_1, obtained at the spatial image transform step, into the two-dimensional object video signal V_2 by the perspective transform matrix P_0. Accordingly, a transform matrix Tobj for obtaining the two-dimensional object video signal V_2 from the source video signal V_0 is expressed as the three-dimensional transform matrix T_0 and the perspective transform matrix P_0 by the following equation:

$$Tobj = T_0 \cdot P_0$$

$$
= \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & 0 \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & 0 \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & 0 \\ l_x & l_y & l_z & s \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

$$
= \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{13}P_z \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{23}P_z \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \gamma_{33}P_z \\ l_x & l_y & l_z & l_z + s \end{bmatrix} \qquad \ldots (3)
$$

In the image processing apparatus using the special effects apparatus according to the present invention, if the two-dimensional source video signal V_0 supplied from the outside is temporarily written in the frame memory 12 and the two-dimensional read address (X_S, Y_S) computed at the read address generating circuit 14 is supplied to this frame memory 12, then a spatial image transform (three-dimensional image transform) desired by the operator may be effected on the video signal read out from the frame memory 12. Accordingly, the source video signal V_0 memorized in the frame memory 12 and the object video signal V_2 read out from the frame memory 12 are both two-dimensional data. That is, in the computation of this two-dimensional read address (X_S, Y_S), data of the Z-axis direction on the three-dimensional space is not used substantially.

Accordingly, parameters of the third raw and the third column for computing the Z-axis direction component of the equation (3) are not required when the read address for the frame memory is computed.

Therefore, let it be assumed that a three-dimensional

transform matrix having parameters necessary for computing the two-dimensional read address in actual practice is T_{33}. Then the above-mentioned matrix T_{33} may be expressed by the following equation in which the parameters on the third row and the third column are removed from the equation (3):

$$T_{33} = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} P_z \\ \gamma_{21} & \gamma_{22} & \gamma_{23} P_z \\ 1_x & 1_y & 1_z P_z + S \end{bmatrix} \qquad \ldots (4)$$

Here, a relationship between a position vector on the frame memory 12 and a position vector on the monitor screen 8 will be described.

In FIG. 5A, let it be assumed that a two-dimensional address and a position vector on the frame memory 12 is (X_M, Y_M) and $[X_M\ Y_M]$ and an address and a position vector on the monitor screen 3 are (X_S, Y_S) and $[X_S\ Y_S]$. If the two-dimensional position vector on this frame memory 12 is expressed by a homogeneous coordinates system, then it may be expressed by a vector $[x_m\ y_m\ H_0]$. Also, if he position vector $[X_S\ Y_S]$ on the monitor screen 55 is expressed by a homogeneous coordinates system, then it may be expressed as a vector $[x_6\ y_6\ 1]$.

Incidentally, the parameter "H_0" of this homogeneous coordinates system is the parameter representing a magnification ratio and a reduction ratio of a size of a vector. In this embodiment, the value of the parameter H_0 is used as pseudo depth information. This parameter H_0 will be described later on.

Effecting the three-dimensional transform matrix T_{33}

on the position vector $[x_m\ y_m\ H_0]$ on the frame memory 12, the position vector $[x_m\ y_m\ H_0]$ on the frame memory 12 is transformed into the position vector $[x_s\ y_s\ 1]$ on the monitor screen 3. Accordingly, a relationship between the position vector $[x_m\ y_m\ H_0]$ on the frame memory 12 and the position vector $[x_s\ y_s\ 1]$ on the monitor screen 3 may be expressed by the following equation:

$$[x_s\ y_s\ 1] = [x_m\ y_m\ H_0] \cdot T_{33} \qquad \ldots (5)$$

Incidentally, the relationship between the parameter "H_0" of the homogeneous coordinates system used in the position vector $[x_m\ y_m\ H_0]$ on the frame memory 12 and the parameter "1" of the homogeneous coordinates system used in the position vector $[x_s\ y_s\ 1]$ on the monitor screen 8 represents that the two-dimensional position vector $[x_m\ y_m]$ on the frame memory 12 is transformed into the two-dimensional position vector $[x_s\ y_s]$ on the monitor screen 3 by the three-dimensional transform matrix T_{33} and that the magnification and reduction ratio "H_0" of the two-dimensional position vector $[x_m\ y_m]$ on the frame memory 12 is transformed into the magnification and reduction ratio "1" of the position vector $[x_s\ y_s]$ of the homogeneous coordinates system on the monitor screen 3.

As described above, the equation (5) is the relation for calculating the points on the monitor screen 2 corresponding to the points on the frame memory 12 by the matrix T_{33}. The image processing apparatus using the special effects apparatus memorizes the source video signal in the state of being transformed, and effects a spatial image transform on the source video signal by

designating the points on the frame memory 12 corresponding to the points on the monitor screen 3 obtained by the transform matrix T_{33} with a read address. That is, the image transform is executed not when data is written in the frame memory but the image transform is executed when data is read out from the frame memory 12.

In such image processing apparatus, the points on the monitor screen 3 corresponding to the points on the frame memory 12 are not computed as in the equation (5) but the points on the frame memory 12 corresponding to the points on the monitor screen 3 should be calculated. Accordingly, the equation (5) is transformed, and the points on the frame memory 12 corresponding to the points on the monitor screen 3 may be obtained by using a relation expressed as:

$$[x_m \ y_m \ H_0] = [x_s \ y_s \ 1] \cdot T_{33}^{-1} \qquad \cdots (6)$$

Thus, when the position vector $[x_s \ y_s \ 1]$ on the monitor screen 3 is designated in accordance with this equation (6), the position vector $[x_m \ y_m \ H_0]$ on the frame memory FM is computed by a transform matrix T_{33}^{-1}. In this connection, this transform matrix T_{33}^{-1} is the inverse matrix of the transform matrix T_{33}.

Then, in order to obtain a two-dimensional position vector $[X_M \ Y_M]$ on the frame memory FM, the transform matrix T_{33} and the inverse matrix T_{33}^{-1} are expressed as follows. That is, respective elements of the transform matrix T_{33} are put as:

$$T_{33} = \begin{bmatrix} r_{11} & r_{12} & r_{13} P_z \\ r_{21} & r_{22} & r_{23} P_z \\ 1_X & 1_Y & 1_Z P_z + s \end{bmatrix}$$

$$= \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

... (7)

and the parameters of the inverse matrix T_{33}^{-1} are expressed by the following equation:

$$T_{33}^{-1} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}^{-1} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

... (8)

where $b_{ij} = \dfrac{a_{ij}}{\det(T_{33})}$

Substituting the equation (8) into the equation (6), we have the following equation expressed as:

$$[x_m\, y_m\, H_0] = [x_s\, y_s\, 1] \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

$$= [b_{11} x_s + b_{21} y_s + b_{31}$$
$$= b_{12} x_s + b_{21} y_s + b_{31}$$
$$= b_{13} x_s + b_{23} y_s + b_{33}]$$

... (9)

Thus, we have the following relation expressed as:

$$x_m = b_{11} x_s + b_{21} y_s + b_{31}$$

$$y_m = b_{12} x_s + b_{22} y_s + b_{32}$$

$$H_0 = b_{13} x_s + b_{23} Y_s + b_{33} \qquad \text{... (10)}$$

Here, the manner in which the position vector $[x_m\ y_m\ H_0]$ of the homogeneous coordinates system on the frame memory 12 is transformed into the two-dimensional position vector $[X_M\ Y_M]$ on the frame memory 12 will be described.

Since the parameter "H_0" used when the two-dimensional position vector $[X_M\ Y_M]$ is expressed by the homogeneous coordinates system is the parameter expressing the magnification and reduction ratios of the position vector $[x_m\ y_m]$ of the homogeneous coordinates system, in order to transform the position vector of the homogeneous coordinates system into the two-dimensional position vector, the parameters "x_m" and "y_m" indicating the direction of the position vector of the homogeneous coordinates system should be normalized by the parameter "H_0" indicating the magnification and reduction ratios of the position vector of the homogeneous coordinates system. Accordingly, the parameters "X_M" and "Y_M" of the two-dimensional vector on the monitor screen 3 may be expressed as:

$$X_M = \frac{x_m}{H_0} \qquad Y_M = \frac{y_m}{H_0} \qquad \ldots (11)$$

Also, when the vector $[x_S\ y_S\ 1]$ of the homogeneous coordinates system on the monitor screen 3 is transformed into the two-dimensional position vector $[X_S\ Y_S]$, similarly, the parameters "x_S" and "y_S" indicative of the direction of the position vector of the homogeneous coordinates system should be normalized by "1" representing the magnification and reduction ratios of the position vector of the homogeneous coordinates system. Accordingly, the

respective parameters "x_s" and "y_s" of the two dimensional position vector on the monitor screen 3 may be expressed by the following equation:

$$X_s = x_s$$
$$Y_s = y_s \qquad \ldots (12)$$

Thus, the two dimensional read address (X_M, Y_M) supplied to the frame memory 12 may be obtained from the equation (10) by the following equations:

$$X_M = \frac{X_m}{H_0}$$
$$= \frac{b_{11}x_s + b_{21}y_s + b_{31}}{b_{13}x_s + b_{23}y_s + b_{33}}$$
$$= \frac{b_{11}x_s + b_{21}b_{21}y_s + b_{31}}{b_{13}x_s + b_{23}y_s + b_{33}}$$
$$\ldots (13)$$

$$Y_M = \frac{y_m}{H_0}$$
$$= \frac{b_{12}x_s + b_{22}y_s + b_{32}}{b_{13}x_s + b_{23}y_s + b_{33}}$$
$$= \frac{b_{12}x_s + b_{22}y_s + b_{32}}{b_{13}x_s + b_{23}y_s + b_{33}}$$
$$\ldots (14)$$

Then, the respective parameters b_{11} to b_{33} of T_{33}^{-1} are obtained.

$$b_{11} = \frac{-a_{32}a_{29} + a_{22}a_{33}}{W_1}$$
$$\ldots (15)$$

$$b_{12}=\frac{a_{32}a_{13}-a_{12}a_{33}}{W_1}$$

... (16)

$$b_{13}=\frac{-a_{22}a_{13}+a_{12}a_{23}}{W_1}$$

... (17)

$$b_{21}=\frac{a_{31}a_{23}-a_{21}a_{33}}{W_1}$$

... (18)

$$b_{22}=\frac{-a_{31}a_{13}+a_{11}a_{33}}{W_1}$$

... (19)

$$b_{23}=\frac{a_{21}a_{13}-a_{11}a_{23}}{W_1}$$

... (20)

$$b_{31}=\frac{-a_{32}a_{31}+a_{21}a_{32}}{W_1}$$

... (21)

$$b_{32}=\frac{a_{12}a_{31}-a_{11}a_{32}}{W_1}$$

... (22)

$$b_{33}=\frac{-a_{12}a_{21}+a_{11}a_{22}}{W_1}$$

... (23)

where

$$W_1 = -a_{23}a_{31}a_{13} + a_{21}a_{32}a_{13} + a_{12}a_{31}a_{23}$$

$$-a_{11}a_{32}a_{23} - a_{12}a_{21}a_{33} + a_{11}a_{22}a_{33}$$

... (24)

Here, the values of a_{11} to a_{33} are obtained based on the relationship described in the equation (7) as:

$$a_{11} = r_{11},\ a_{12} = r_{12},\ a_{13} = r_{13}P_z \qquad \text{... (25)}$$

$$a_{21} = r_{21},\ a_{22} = r_{22},\ a_{23} = r_{23}P_z \qquad \text{... (26)}$$

$$a_{31} = l_x,\ a_{32} = l_y,\ a_{33} = l_zP_z + s \qquad \text{... (27)}$$

Substituting these values into the equations (15) to (24), we have:

$$b_{11} = \frac{-l_y r_{23} P_z + r_{22}(l_z P_z + s)}{W_1} \qquad \text{... (28)}$$

$$b_{12} = \frac{l_y r_{13} P_z + r_{12}(l_z P_z + s)}{W_1} \qquad \text{... (29)}$$

$$b_{13} = \frac{-r_{22} r_{13} P_z + r_{12} r_{33} P_z}{W_1} \qquad \text{... (30)}$$

$$b_{21} = \frac{l_x r_{23} P_z - r_{21}(l_z P_z + s)}{W_1} \qquad \text{... (31)}$$

$$b_{22} = \frac{-l_x r_{13} P_z + r_{11}(l_z P_z + s)}{W_1} \qquad \text{... (32)}$$

$$b_{23} = \frac{r_{21} r_{13} P_z - r_{11} r_{23} P_z}{W_1} \qquad \text{... (33)}$$

$$b_{31} = \frac{-r_{22} l_x + r_{21} l_y}{W_1} \qquad \text{... (34)}$$

$$b_{32} = \frac{r_{12} l_x - r_{11} l_y}{W_1} \qquad \text{... (35)}$$

$$b_{33} = \frac{-r_{12} r_{21} + r_{11} r_{22}}{W_1} \qquad \text{... (36)}$$

$$W_1 = -r_{22}l_x \quad r_{13}P_z + r_{21}l_y r_{13}P_z + r_{12}l_x r_{23}P_z$$
$$- r_{11}l_y r_{23}P_z - r_{12}r_{21}(l_z P_z + s) + r_{11}r_{22}(l_z P_z + s)$$

... (37)

Thus, substituting the values of the equations (28) to (37) into the equations (18) and (14), the read address (X_M, Y_M) supplied to the frame memory 12 may be expressed as:

$$X_M = \frac{1}{H_0}[\{-l_x r_{23}P_z + r_{22}(l_z P_z + s)\}X_s$$
$$+ \{l_y r_{13}P_z + r_{12}(l_z P_z + s)\}Y_s$$
$$+ (-r_{22}r_{13}P_z + r_{12}r_{23}P_z)]$$

... (38)

$$Y_M = \frac{1}{H_0}[\{l_x r_{23}P_z - r_{21}(l_z P_z + s)\}X_s$$
$$+ \{-l_x + r_{11}(l_z P_z + s)\}Y_s$$
$$+ \{r_{21}r_{13}P_z - r_{11}r_{23}P_z\}]$$

... (39)

where H_0 is given by the following equation:

$$H_0 = (-r_{22}l_x + r_{21}l_y)\ X_s$$
$$+ (r_{12}l_x - r_{11}l_y)\ Y_s$$
$$+ (-r_{12}r_{21} + r_{11}r_{22}) \qquad \text{... (40)}$$

Therefore, the read address (X_M, Y_M) supplied to the frame memory 12 may be expressed by using the respective parameters (r_{11} to r_{33}, l_x, l_y, l_z and s) of the three-dimensional transform matrix T_0 determined by the desired spatial image transform apparatus of the operator and the perspective value P_z which is the previously-set parameter.

Accordingly, by supplying the addressing screen

address (X_s, Y_s) corresponding to the raster scanning of the monitor screen 3 to the equations (6) to (40), the read address (X_M, Y_M) on the frame memory 12 corresponding to the supplied screen address may be computed sequentially.

As mentioned before, in this embodiment, the value of the parameter H_0 calculated by the equation (40) is used as the depth information. The reason for this is that Z coordinate value of the actual three-dimensional space in the three-dimensional transform is proportional to the parameter H_0.

If the actual Z coordinate value in the three-dimensional space is not used as the depth information and the value of the parameter H calculated in the equation (40) is used, there are achieved the following effects. That is, when the depth information is computed, the actual Z coordinates value need not be computed so that the one-dimensional computation may be omitted. Thus, a three-dimensional transform high-speed processor need not be used, and hence depth information may be computed by using a low-speed processor. Further, this parameter H_0 is held at the value which is required to compute the two-dimensional read address supplied to the frame memories 12, 13, some special computation is not required in order to obtain this parameter H_0. Accordingly, it is possible to execute a higher-speed computation.

The thus obtained parameter H_0 means that an interval between the sampling addresses (x, y) of the read address spaces of the frame memories 12, 13 is "H_0" as shown in FIG. 6(A) when an interval between the spatial sampling address (x_s, Y) on the screen

surface 55A, i.e. an interval between the pixels on the screen surface 55A is set to "1" as shown in FIG. 6(B). Incidentally, in FIG. 6(B), an open circle represents data memorized in the frame memory, and a mark cross represents a read address point.

Accordingly, if the value of the parameter H_0 serving as the depth information H_0 increases, then the value of the read address $(x_M/H_0,\ y_M/H_0)$, normalized in the equations (13) and (14), of the frame memories 12, 13 decreases. If the interval between the read addresses of the frame memories 12, 13 decreases as described above, then the number of pixels developed on the screen surface 55 increases with the result that an image displayed on the screen surface 55 is magnified.

If on the other hand the parameter H_0 decreases, then the value of the normalized read address $(x_M/H_0,\ y_M/H_0)$ of the frame memories 12, 13 increases, thereby resulting in the interval between the spatial read addresses of the frame memories being increased. However, if the interval between the spatial read addresses increases, then when data read out from the frame memories 12, 13 is displayed on the screen surface 55A, a displayed image is reduced in scale.

As shown in FIG. 7(B), for example, when image data is read out by the read address of the area ER2 whose parameter H_0 is made different in accordance with the perspective so as to cross the memory area ER1 which is designated without the perspective in the address space of the frame memories 12, 13, the image displayed on the screen surface 55A is displayed on the screen

surface 55A in its area ERIX as an image, which is not based on the perspective, because image data read out from the area ER1 of the frame memories 12, 13 without the perspective is read out by the spatial read sampling address determined by the same parameter H_0 over the whole area ER1 as shown in FIG. 7(A).

On the other hand, the image data which results from reading pixel data of the frame memories 12, 13 in accordance with the perspective from the area ER2 in which the spatial interval between the sampling addresses is different is represented as an image reduced on the screen surface 55A at the read sampling address portion having the large parameter H_0 and is also represented as an image reduced on the screen surface 55A in the area in which the parameter H_0 is decreased and the interval between the sampling addresses is increased.

Since the change of the magnitude of the parameter H_0 functions as the depth information as described above, it is possible to display the image using the perspective on the screen surface 55A.

(4) DESCRIPTION OF SHADOW COORDINATES SYSTEM:

The shadow coordinates system will be described next with reference to FIG. 8. The shadow coordinates system is a coordinates system defined by the three-dimensional orthogonal coordinates system comprising Xs, Ys and Zs axes similarly to the world coordinates system. As shown in FIG. 8, assuming that the shadow given to the object video signal Vobj is a shadow video signal shadow, then a plane onto which the shadow video signal is projected

is set as an XY plane of the shadow coordinates system and this plane is referred to as a shadow plane. A direction in which a light source for giving the shadow of the object video signal Vobj exists is assumed to be a negative direction of the Z axis of the shadow coordinates system. In the following description, the special effects apparatus according to the present invention include a point source mode for generating a shadow by using a point source and a parallel light source mode for generating a shadow by using a parallel light source which can be set freely by the operator. Angles of the Xs, Ys and Zs axes of the shadow coordinates system relative to the X, Y and Z axes of the world coordinates system may be freely set by the operator.

(5) DESCRIPTION OF TRANSFORM PROCESSING FOR GENERATING A SHADOW VIDEO SIGNAL IN THE POINT SOURCE MODE:

Initially, the transform processing for generating a shadow video signal V_4 by transforming the source video signal in the point source mode will be described with reference to FIGS. 9A and 9B. Incidentally, with respect to FIGS. 9A and 9B, FIG. 9A is a diagram showing the XY plane of the world coordinates system from a visual point PZ set on the Z axis of the world coordinates system, and FIG. 9B is a diagram showing the YZ plane of the world coordinates system from the position of the positive direction of the X axis of the world coordinates system similarly to FIGS. 4A and 4B.

As earlier noted with reference to FIGS. 4A and 4B, the three-dimensional object video signal V_I, which was transformed

to the three-dimensional spatial position by the three-dimensional transform matrix T_0, was perspective-transformed into the X_sY_s plane of the shadow coordinates by the perspective transform matrix P_{SPOT} based on the point source. This means that the video signal projected onto the X_sY_s plane of the shadow coordinates system when the three-dimensional object video signal V_I is seen from the point source 90 if the point source 90 is used as a visual point. In FIG. 9B, the video signal projected onto the X_sY_s plane of the shadow coordinates system is represented as a three-dimensional shadow video signal V_3. The perspective transform matrix P_{SPOT} based on this point source will be described in detail later on.

Then, the three-dimensional shadow video signal V_3 is perspective-transformed into the XY plane of the world coordinates system by the earlier-described perspective transform matrix P_0. This means that a video signal projected onto the XY plane of the world coordinates system is obtained when the three-dimensional shadow video signal V_3 is seen from the virtual visual point PZ on the Z axis. In FIG. 9B, the video signal projected onto the XY plane of the world coordinates system is represented as a two-dimensional shadow video signal V_4..

The above-mentioned processing shown in FIG. 9B will be summarized. In the point source mode, the transform processing for obtaining the two-dimensional shadow video signal V_4 from the two-dimensional source video signal V_0 comprises a three-dimensional transform step for obtaining the three-dimensional object video signal V_I by three-dimensional-transforming the object

video signal V_0, a perspective-transforming step for obtaining the three-dimensional shadow video signal V_3 by projecting this three-dimensional object video signal V_I onto the $X_S Y_S$ plane of the shadow coordinates system by the perspective-transform matrix P_{SPOT} based on the point source and a step for obtaining the two-dimensional shadow video signal V_4 by projecting this three-dimensional shadow video signal V_3 by the perspective-transform matrix P_0. Thus, the transform matrix Tshadow' for obtaining the two-dimensional shadow video signal V_4 may be expressed by the following equation:

$$\text{Tshadow}' = T_0 \cdot P_{SPOT} \cdot P_0 \qquad \ldots (41)$$

Here, a relationship between the position vector on the frame memory 22 and the position vector on the monitor screen 3 will be described.

Similarly to the relationship between the position vector on the frame memory 12 and the position vector on the monitor screen 3, in FIG. 9C, (X_M', Y_M') assumes a two-dimensional address on the frame memory 22, (X_S, Y_S) assumes an address on the monitor screen 3 and $[X_S\ Y_S]$ assumes a position vector. The two-dimensional position vector $[X_M'\ Y_M']$ on the frame memory 22 may be expressed as $[x_m'\ y_m'\ H_S']$ by the homogeneous coordinates system. Also, the position vector $[X_S\ Y_S]$ on the monitor screen 55 may be expressed as a vector $[x_s\ y_s\ 1]$ by the homogeneous coordinates system.

Here, the parameter $[H_S]$ of this homogeneous coordinates system is the parameter representing the magnification and reduction ratios of the magnitude of the vector similarly to

the parameter of the homogeneous coordinates system obtained when the position vector on the frame memory 12 is expressed by the homogeneous coordinates system. In this embodiment, this parameter is used as pseudo-depth information. This parameter "H_s" will be described later on.

The transform matrix Tshadow' for obtaining the two-dimensional shadow video signal V4 from the two-dimensional source video signal V_0 is a transform matrix of 4 rows and 4 columns, although it will be described later on, in which data of the Z-axis direction (third row and third column) on the three-dimensional space is not used substantially and the position vector [x_m' y_m' H_s] on the frame memory 22 is transformed into the position vector [x_s y_s 1] on the monitor screen 3 by causing this three-dimensional transform matrix T_{33}shadow' to act on the position vector [x_m' y_m' H_s] on the frame memory 22 in which T_{33}shadow' represents the three-dimensional transform matrix having parameters necessary for computing the actual two-dimensional read address. A relation may be expressed as:

$$[x_s\ y_s\ 1] = [x_m'\ y_m'\ H_s] \cdot T_{33}\text{shadow}' \qquad \ldots (5)'$$

Incidentally, the relationship between the parameter "H_s" of the homogeneous coordinates system used in the position vector [x_m' y_m' H_s] on the frame memory 22 and the parameter "1" used in the position vector [x_s y_s 1] on the monitor screen 5 means that the two-dimensional position vector [x_m' y_m'] on the frame memories 22, 23 is transformed into the two-dimensional position vector [x_s y_s] on the monitor screen 22 by the three-dimensional

transform matrix T_{33}shadow so that the magnification and reduction ratio "H_S" of the two-dimensional position vector [x_m' y_m'] on the frame memory 22 becomes the magnification and reduction ratio "1" of the position vector [x_S y_S] of the homogeneous coordinates on the monitor screen 22.

As described above, the equation (5)' is the relation for obtaining the point on the monitor screen 2 corresponding to the point on the frame memory 22 by the matrix T_{33}shadow'. Similarly when data is read out from the frame memory 12, a spatial image transformation is effected on the mat source video signal by designating the point on the frame memory 22 corresponding to the point on the monitor screen obtained by the transform matrix T_{33}shadow'. That is, the image transformation is not executed when data is written on the frame memory 22 but the image transformation is executed when data is read out from the frame memory 22.

The manner in which the point on the frame memory 22 corresponding to the point on the monitor screen 3 is obtained is expressed by the following equation:

$$[x_m' \ y_m' \ H_S] = [x_S \ y_S \ 1] \cdot (T_{33}\text{shadow}')^{-1} \quad \ldots (6)'$$

Thus, when the position vector [x_S y_S 1] on the monitor screen 3 is designated in accordance with this equation, the position vector [x_m' y_m' H_S] on the frame memory 22 is computed by the transform matrix (T_{33}shadow'). In this connection, this transform matrix $(T_{33}\text{shadow}')^{-1}$ is the inverse matrix of the transform matrix T_{33}shadow'.

Then, the perspective transform matrix P_{SPOT} based on the point source obtained when the point source is used will be described with reference to FIGS. 10 and 11. FIG. 10 is a diagram showing the $Y_S Z_S$ plane from the Xs-axis direction of the shadow coordinates system, and shows a relationship among the point source 60, the three-dimensional object video signal V_1 and the three-dimensional shadow video signal V_3. The perspective transform matrix P_{SPOT} based on the point source is the transform matrix for obtaining the three-dimensional shadow video signal V_3 from the three-dimensional object video signal V_1 in the point source mode using the point source.

FIG. 11A shows a flowchart for effecting a transform processing on the point source 60, and FIG. 11B is a flowchart for effecting a transform processing on the object video signal.

Initially, the transform processing flowchart for the point source 60 will be described with reference to FIG. 11A.

In a step SP1, the position of the point source 60 shown by the world coordinates system is transformed by the transform matrix F^{-1} into the shadow coordinates system. The reason for this is that a perspective transform matrix P_{SO}', which will be described in the later step SP5, is not the perspective transform matrix of the world coordinates system but the perspective transform matrix in the shadow coordinates system. Thus, when the three-dimensional object video signal V_1 is projected onto the $X_S Y_S$ plane of the shadow coordinates system, the position of the point source 60 expressed by the world coordinates system should be transformed into the

shadow coordinates system.

Here, this transform matrix F^{-1} will be described concretely. Initially, θ_X assumes the rotation angle of the Xs axis of the shadow coordinates system relative to the X axis of the world coordinates system, θ_Y assumes a rotation angle of the Ys axis of the shadow coordinates system relative to the Y axis of the world coordinates system, θ_Z assumes a rotation angle of the Zs axis of the shadow coordinates system relative to the Z axis of the world coordinates system, and (X_{s0}, y_{s0}, Z_{s0}) assumes the origin of the shadow coordinates system. Since the transform matrix F from the shadow coordinates to the world coordinates system, which is the inverse matrix of the transform matrix F^{-1} from the world coordinates system to the shadow coordinates system may be simply expressed by a product of the rotation matrix and the movement matrix, initially, there is obtained the transform matrix F from the shadow coordinates system to the world coordinates system. The transform matrix F from the shadow coordinates system to the world coordinates system may be expressed by the following equation:

$$F = R_X(\theta_X) \cdot R_Y(\theta_Y) \cdot R_Z(\theta_Z) \cdot L(x_{s0}, y_{s0}, z_{s0}) \quad \text{... (42)}$$

where matrix $R_X(\theta_X)$, matrix $R_Y(\theta_Y)$ and matrix $R_Z(\theta_Z)$ are rotation matrixes and may be expressed as:

$$R_x(\theta_x) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta x & \sin\theta x & 0 \\ 0 & -\sin\theta x & \cos\theta x & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{... (43)}$$

$$R_Y(\theta_Y)=\begin{bmatrix}\cos\theta y & 0 & -\sin\theta y & 0\\ 0 & 1 & 0 & 0\\ \sin\theta y & 0 & -\cos\theta y & 0\\ 0 & 0 & 0 & 1\end{bmatrix} \quad \cdots (44)$$

$$R_Z(\theta_Z)=\begin{bmatrix}\cos\theta z & \sin\theta z & 0 & 0\\ -\sin\theta z & \cos\theta z & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix} \quad \cdots (45)$$

Also, the matrix $L(x_{so}, y_{so}, z_{so})$ is the parallel movement matrix and may be expressed by the following equation:

$$L(x_{so},y_{so},z_{so})=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ x_{so} & y_{so} & z_{so} & 1\end{bmatrix} \quad \cdots (46)$$

Thus, since the transform matrix F from the shadow coordinates system to the world coordinates system and the transform matrix F^{-1} from the world coordinates system to the shadow coordinates system are in a relationship of the inverse matrix, the transform matrix F^{-1} may be expressed as:

$$\begin{aligned}F^{-1} &= L^{-1}(x_{so}, y_{so}, z_{so}) \cdot R_X^{-1}(\theta_X) \cdot R_Y^{-1}(\theta_Y) \cdot R_Z^{-1}(\theta_Z)\\ &= L(-x_{so}, -y_{so}, -z_{so}) \cdot R_X(-\theta_X) \cdot R_Y(-\theta_Y) \cdot R_Z(-\theta_Z)\end{aligned} \quad \cdots (47)$$

where the matrix $R_X(-\theta_X)$, the matrix $R_Y(-\theta_Y)$ and the matrix $R_Z(-\theta_Z)$ are the rotation matrixes and may be expressed as:

$$R_X(-\theta x)=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & \cos(-\theta x) & \sin(-\theta x) & 0\\ 0 & -\sin(-\theta x) & \cos(-\theta x) & 0\\ 0 & 0 & 0 & 1\end{bmatrix} \quad \cdots (48)$$

$$R_Y(-\theta y) = \begin{bmatrix} \cos(-\theta y) & 0 & -\sin(-\theta y) & 0 \\ 0 & 1 & 0 & 0 \\ \sin(-\theta y) & 0 & \cos(-\theta y) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \cdots (49)$$

$$R_Z(-\theta z) = \begin{bmatrix} \cos(-\theta z) & \sin(-\theta z) & 0 & 0 \\ -\sin(-\theta z) & \cos(-\theta z) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \cdots (50)$$

Also, the matrix L $(-X_{s0}, -Y_{s0}, -Z_{s0})$ are the parallel movement matrix and may be expressed as:

$$L(-x_{s0}, -y_{s0}, -z_{s0}) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_{s0} & -y_{s0} & -z_{s0} & 1 \end{bmatrix}$$

$$\cdots (51)$$

In a step SP2, as shown in FIG. 10, by a parallel movement matrix Y_{XSYS}^{-1}, the position of the point source 90 is moved to the position of the virtual point source 91 on the Zs axis. The reason for this is that, in order to obtain the three-dimensional video signal V_3 relative to the three-dimensional object video signal V_1, when the three-dimensional object video signal V_1 is seen, the three-dimensional shadow video signal V_3 may be obtained by projecting the three-dimensional object video signal V_1 onto the X_SY_S plane of the shadow coordinates system. In order to execute this perspective transform processing, the point source serving as the visual point should be positioned on the Zs axis. Therefore, by the parallel movement matrix T_{XSYS}^{-1}, the position of the point source 90 is parallelly moved to the position of the virtual point

source 91 on the Zs axis.

Assuming that (x_L, y_L, z_L) is the coordinates of the point source 90 previously set by the operator, then this parallel movement matrix T_{XSYS}^{-1} may be expressed as:

$$T_{XSYS}^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -x_L & -y_L & 0 & 1 \end{bmatrix} \qquad \ldots (52)$$

The transform processing for the point source is ended by the steps SP1 and SP2.

The perspective transform matrix P_{SPOT} for generating the three-dimensional shadow video signal V_3 from the three-dimensional object video signal V_1 will be described next with reference to FIG. 11B.

In a step SP3, similarly to the step SP1, the three-dimensional object video signal V_1 expressed by the world coordinates system is transformed into the shadow coordinates system by the transform matrix F^{-1}. The reason for this is that a perspective transform matrix P_{S0}' used in a step SP5, which will be described later on, is not the perspective transform matrix in the world coordinates system but the perspective transform matrix in the shadow coordinates system. When the three-dimensional object video signal V_1 is projected onto the X_SY_S plane of the shadow coordinates system by the perspective transform matrix P_{S0}', the three-dimensional object video signal V_1 expressed by the world coordinates system should be transformed into the shadow coordinates system.

In a step SP4, similarly to the step SP2, as shown in FIG. 10, the three-dimensional object video signal V_1 is parallelly moved to the X_SY_S plane of the shadow coordinates system by the parallel movement matrix T_{XSYS}^{-1}. In FIG. 10, the parallelly-moved video signal is expressed as a virtual three-dimensional object video signal V_1'. The reason that the three-dimensional object video signal is moved parallelly will be described below. Since the position of the point source 90 is parallelly moved to the position of the virtual light source 91 on the Zs axis at the step SP2, the three-dimensional object video signal V_1 also should be parallelly moved by the parallel movement matrix T_{XSYS}^{-1} in such a manner the relative relationship between the point source 90 and the three-dimensional object video signal V_1 and the relative relationship between the virtual point source 91 and the virtual object video signal V_1' may not be changed.

In the next step SP5, the virtual three-dimensional object video signal V_1' is projected onto the X_SY_S plane of the shadow coordinates system by the perspective transform matrix P_{S0}'. In FIG. 10, the video signal projected onto the X_SY_S plane of the shadow coordinates system is expressed as a virtual three-dimensional video signal V_3'. This virtual three-dimensional shadow video signal V_3' is the video signal projected onto the X_SY_S plane of the shadow coordinates system when the virtual three-dimensional object video signal V_1' is seen from the virtual point source 91 where the virtual point source 91 is employed as the visual point.

Specifically, in this perspective transform matrix P_{S0}',

it may be considered that, from the relationship between the perspective transform matrix P_0 shown in the equation (2) and the visual point PZ, the visual point in the perspective may be located at the position of the virtual point source 91, i.e. the position of $(0, 0, Z_L)$. Thus, it is possible to obtain the perspective transform matrix P_{S0}' by replacing "Pz" with "$-1/Z_L$" in the equation (2). Thus, the perspective transform matrix P_{S0}' may be expressed as:

$$P_{S0}' = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1/Z_L \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \ldots (53)$$

In the next step SP6, by the parallel movement matrix T_{XSYS}, the virtual three-dimensional shadow video signal V_3' is parallelly moved to the X_SY_S plane of the shadow coordinates system. In FIG. 10, the thus parallelly-moved video signal is expressed as the three-dimensional shadow video signal V_3. As will be seen from FIG. 10, the three-dimensional shadow video signal V_3 is the video signal projected onto the X_SY_S plane of the shadow coordinates system when the three-dimensional object video signal V_1 is seen from the position of the point source 90 where the point source 90 is employed as the visual point. The reason that the video signal is moved parallelly is that, since the three-dimensional object video signal V_1 is parallelly moved by the parallel movement matrix T_{XSYS}^{-1} at the step SP4, the parallel movement processing executed by the parallel movement matrix T_{XSYS}^{-1} should be returned to the original state.

Here, since the parallel movement matrix T_{xsys}^{-1} and the parallel movement matrix T_{xsys} are placed in the relationship of the inverse matrix, the parallel movement matrix T_{xsys} may be expressed as:

$$T_{xsys} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ x_L & y_L & 0 & 1 \end{bmatrix} \qquad \cdots (54)$$

In the next step SP7, by the transform matrix F expressed in the equation (42), the three-dimensional shadow video signal V_3 is transformed into the world coordinates system. Thus, there may be obtained the three-dimensional shadow video signal V_3 represented by the coordinates values of the world coordinates system.

The processing shown in the flowchart of FIG. 11B will be summarized. The processing for obtaining the three-dimensional shadow video signal from the three-dimensional object video signal V_1 of the world coordinates system comprises the step (SP3) for transforming the three-dimensional object video signal V_1 from the world coordinates system to the shadow coordinates system, the steps (SP4, SP5 and SP6) for generating the three-dimensional shadow video signal of the shadow coordinates system by projecting the three-dimensional object video signal onto the X_SY_S plane of the shadow coordinates system in the shadow coordinates system and the step (SP7) for transforming the three-dimensional shadow video signal of the shadow coordinates system from the shadow coordinates system to the world coordinates system.

Accordingly, the perspective transform matrix P_{SPOT} based on the point source for obtaining the three-dimensional shadow video signal of the world coordinates system from the three-dimensional object video signal V_1 of the world coordinates system may be expressed by a multiplication of the transform matrix F^{-1}, the parallel movement matrix T_{xsys}^{-1}, the perspective transform matrix P_{S0}', the parallel movement matrix T_{xsys}^{-1} and the transform matrix F^{-1}, and hence may be expressed by the following equation:

$$P_{SPOT} = F^{-1} \cdot T_{xsys}^{-1} \cdot P_{S0}' \cdot T_{xsys}' \cdot F^{1} \qquad \text{... (55)}$$

Thus, by substituting this transform matrix P_{SOPT} into the equation (41), the transform matrix Tshadow' for obtaining the two-dimensional shadow video signal V_4 from the two-dimensional source video signal in the point source mode may be expressed as:

$$\begin{aligned} \text{Tshadow}' &= T_0 \cdot P_{SPOT} \cdot P_0 \\ &= T_0 \cdot F^{-1} \cdot T_{xsys}^{-1} \cdot P_{S0}' \cdot T_{xsys}^{1} \cdot F^{1} \end{aligned} \qquad \text{... (55)}$$

Here, the method of computing the read address for reading out the shadow video signal V_4 from the frame memory 22 based on this transform matrix Tshadow' is exactly the same as the method of computing the read address (X_M, Y_M) for reading the object video signal V_2 from the frame memory 12 based on the matrix Tobj expressed in the equation (3). That is, the above computation method is exactly the same as the computations expressed in the equations (3) to (14).

Specifically, since this transform matrix Tshadow' is

the matrix of 4 rows and 4 columns, similarly to the equation (4), T_{33}shadow' assumes the matrix excepting the Z-axis direction component (third row and third column) and the respective parameters of the inverse matrix (T_{33}shadow') of this matrix T_{33}shadow' are expressed as:

$$(T_{33}shadow')^{-1} = \begin{bmatrix} b_{11}' & b_{12}' & b_{13}' \\ b_{21}' & b_{22}' & b_{23}' \\ b_{31}' & b_{32}' & b_{33}' \end{bmatrix} \qquad \ldots (57)$$

Also, (X_M', Y_M') assumes the read address supplied from the read address generating circuit 24 in the shadow signal generating unit 20. Referring to the computation method shown from the equation (3) to (14), this read address (X_M', Y_M') may be expressed by the following equations:

$$X_M' = \frac{b_{11}'X_S + b_{21}'Y_S + b_{31}'}{b_{13}'X_S + b_{23}'Y_S + b_{33}'} \qquad \ldots (58)$$

$$Y_M' = \frac{b_{12}'X_S + b_{22}'Y_S + b_{32}'}{b_{13}'X_S + b_{23}'Y_S + b_{33}'} \qquad \ldots (59)$$

Thus, the read address (X_M', Y_M') supplied to the frame memory 22 may be expressed by using the respective parameters (r_{11} to r_{33}, l_x, l_y, y_z and s) of the three-dimensional transform matrix T_0 determined by the operator's desired spatial image transform processing, the perspective value Pz which is the previously-set parameter, the point source position (x_L, y_L, z_L), the rotation angles (θ_x, θ_y, θ_z) of the respective axes of the shadow coordinates system and the positions (x_{s0}, y_{s0}, z_{s0}) of the origin of the shadow coordinates system.

Accordingly, if the screen address (X_S, Y_S) is supplied to the equations (6) to (40) so as to correspond to the raster scanning order of the monitor screen 3, then the read address (X_M', Y_M') on the frame memory 22 corresponding to the supplied screen address may be computed sequentially. Thus, it is possible to generate the two-dimensional shadow video signal V_4 corresponding to the two-dimensional object video signal V_2.

(6) DESCRIPTION OF TRANSFORM PROCESSING FOR GENERATING SHADOW VIDEO SIGNAL IN THE PARALLEL LIGHT SOURCE MODE:

Initially, with reference to FIGS. 12A and 12B, there will be described the transform processing for obtaining a three-dimensional shadow video signal V_5 from the three-dimensional video signal V_1 in the parallel light source mode using the parallel light source. FIGS. 12A and 12B are similar to FIGS. 9A and 9B, wherein FIG. 12A is a diagram showing the XY plane of the world coordinates system from the visual point PZ set on the Z axis of the world coordinates system and FIG. 12B is a diagram showing the YZ plane of the world coordinates system from the position of the positive direction of the X axis of the world coordinates system.

Initially, the three-dimensional object video signal V_1 transformed at the three-dimensional spatial position by the three-dimensional transform matrix T_0 is projected onto the X_SY_S plane of the shadow coordinates system by the perspective transform matrix P_{PARA} based on the parallel light source. In FIG. 12B, the video signal projected onto the X_SY_S plane of the shadow coordinates

system is represented as the three-dimensional shadow video signal V_5. The perspective transform matrix P_{PARA} based on the parallel light source is the transform matrix for obtaining the three-dimensional shadow video signal V_5 by perspective-transforming the three-dimensional object video signal V_1.

Then, the three-dimensional shadow video signal V_5 is projected onto the XY plane of the world coordinates system by the aforementioned perspective transform matrix P_0. This means that the video signal projected onto the XY plane of the world coordinates system is obtained when the three-dimensional shadow video signal V_5 is seen from the virtual visual point PZ on the Z axis. In FIG. 12B, the video signal projected onto the XY plane of the world coordinates system is represented as a two-dimensional shadow video signal V_6.

The processing shown in the flowchart of FIG. 13B will be summarized. The transform processing for obtaining the two-dimensional shadow video signal V_6 from the two-dimensional source video signal V_0 in the parallel light source mode comprises the three-dimensional transform step for obtaining the three-dimensional object video signal V_1 by three-dimensional-transforming the source video signal V_0 by the three-dimensional transform matrix T_0, the perspective-transform step for obtaining the three-dimensional shadow video signal V_5 by projecting this three-dimensional object video signal V_1 onto the X_SY_S plane of the shadow coordinates system by the perspective transform matrix P_{PARA} based on the parallel light source and the step of obtaining the

two-dimensional shadow video signal V_6 by projecting this three-dimensional shadow video signal V_5 onto the XY plane of the world coordinates system by the perspective transform matrix P_0. Thus, the transform matrix Tshadow" for obtaining the two-dimensional shadow video signal V_6 from the two-dimensional source video signal V_0 may be expressed by the following equation (60):

$$Tshadow'' = T_0 \cdot P_{PARA} \cdot P_0 \qquad \ldots (60)$$

With respect to the relationship between the position vector on the frame memory 22 and the position vector on the monitor screen 3 in the parallel light source mode, when $(X_M'' \ Y_M'')$ and $[X_M'' \ Y_M'']$ represent the read address supplied from the read address generating circuit 24 of the shadow signal generating unit 20 and the position vector and $(X_S \ Y_S)$ and $[X_S \ Y_S]$ represent the address and the position vector on the monitor screen 3 similarly to the relationship in the aforementioned light source mode, if they are respectively expressed by the homogeneous coordinates, then they are expressed as $[x_m'' \ y_m'' \ H_s]$ and $[x_s \ y_s \ 1]$, respectively.

When a transform matrix having parameters necessary for computing the actual two-dimensional read address for obtaining the two-dimensional shadow video signal V4 from the two-dimensional source video signal V0 is expressed as a transform matrix T_{33}shadow" which will be described later on, a relationship between a homogeneous coordinates system position vector $[x_m'' \ y_m'' \ H_s]$ on the frame memory 22 and a homogeneous coordinates system position vector $[x_s \ y_s \ 1]$ on the monitor screen 3 is expressed as follows:

$$[x_s \ y_s \ 1] = [x_m'' \ y_m'' \ H_s] \cdot T_{33}shadow'' \qquad \ldots (5)''$$

Accordingly, the point on the frame memory 22 corresponding to the point on the monitor screen 3 may be obtained by the following equation:

$$[x_m'' \ y_m'' \ H_s] = [x_s \ y_s \ 1] \cdot (T_{33}\text{shadow}'')^{-1} \quad \ldots (6)''$$

A perspective transform matrix P_{PARA} obtained by a parallel light source when the parallel light source is in use will be described next with reference to FIGS. 13 to 16.

FIG. 13A shows a flowchart of a transform processing for a parallel light source 70, and FIG. 13B shows a flowchart of a transform processing for a three-dimensional object video signal V_1.

Initially, the flowchart of the transform processing for the parallel light source 70 will be described with reference to FIG. 13A.

At a step SP11, coordinates of the parallel light source 70 defined by spherical coordinates in the world coordinates system are transformed into orthogonal coordinates in the world coordinates system. The position of the parallel light source is generally expressed by the spherical coordinates system rather than the orthogonal coordinates system. The spherical coordinates system is a coordinates system for expressing the position of the parallel light source by "radius (r)", " latitude (α)" and "longitude (β)". FIG. 14A is a diagram showing a relationship between the orthogonal coordinates and the spherical coordinates in the world coordinates system. As shown in FIG. 12A, in a

relationship between the orthogonal coordinates and the spherical coordinates, the standard of the latitude (α) is set to the negative direction of the Y axis, and the standard of the longitude is set to the XY plane. That is, the equator plane of the spherical coordinates agrees with the XY plane of the orthogonal coordinates, and the direction of latitude 0 (rad) and longitude 0 (rad) agrees with the negative direction of the Y axis. Thus, assuming that (r, α, β) is the position of the parallel light source 70 defined by the spherical coordinates and that (x_L, y_L, z_L) is the position of the parallel light source transformed into the orthogonal coordinates, then this light source position (x_L, y_L, z_L) is expressed as:

$$\left.\begin{aligned} x_L &= r \quad \cos\beta \quad \cos\alpha \\ y_L &= r \quad \cos\beta \quad \sin\alpha \\ z_L &= -r \quad \sin\beta \end{aligned}\right\} \qquad (61)$$

Therefore, in order to transform the position of the light source defined by the spherical coordinates into the orthogonal coordinates, by substituting the light source position (r, α, β) of the spherical coordinates system set by the operator into this equation (61), it is possible to obtain the light source position (x_L, y_L, z_L) transformed into the orthogonal coordinates.

At a step SP12, the coordinates of the parallel light source are transformed by a transform matrix F^{-1} are transformed from the world coordinates system into a shadow coordinates system. The transform matrix F^{-1} has been described at the step SP1 and therefore need not be described. Assuming that the light source

position transformed into the shadow coordinates system is (x_L', y_L', z_L'), then a relationship among a vector $[x_L\ y_L\ z_L\ 1]$ of light source in the world coordinates system expressed by a homogeneous coordinates system, a vector $[x_L'\ y_L'\ z_L'\ 1]$ of light source at the shadow coordinates system expressed by the homogeneous coordinates system and the transform matrix F^{-1} may be expressed by the following equation:

$$[x_L'\ y_L'\ z_L'\ 1]$$

$$= [x_L\ y_L\ z_L\ 1] \cdot F^{-1} \qquad \ldots (62)$$

At a step SP13, the light source position (x_L', y_L', z_L') at the orthogonal coordinates in the shadow coordinates system obtained at the step SP12 is transformed so as to be expressed by the spherical coordinates in the shadow coordinates system. FIG. 14B is a diagram showing a relationship between the orthogonal coordinates and the spherical coordinates in the shadow coordinates system. As shown in FIG. 14B, in the relationship between the orthogonal coordinates system and the spherical coordinates system in the shadow coordinates system, a standard of a latitude (α_s) is set to the negative direction of an Y_s axis and a standard of a longitude (β_s) is set to a XsYs plane. That is, the equator plane of the spherical coordinates agrees with the XsYs plane of the orthogonal coordinates, and the direction of latitude 0 (rad) and longitude 0 (rad) agrees with the negative direction of the Ys axis.

Thus, a relationship between the light source position (x_L', y_L', z_L') expressed by the orthogonal coordinates in the shadow coordinates system and the light source position (r', α', β')

expressed by the spherical coordinates is expressed as:

$$\left.\begin{array}{c} r' = Sqrt\{(x_L')^2 + (y_L')^2 + (z_L')^2\} \\ \alpha' = \tan^{-1}(-x_L', y_L') \\ \beta' = \sin^{-1}(-z_L', r) \end{array}\right\} \qquad \ldots (63)$$

Thus, by substituting the light source position (x_L', y_L', z_L') obtained at the step SP12 into this equation (63), it is possible to express the position of the parallel light source 70 by the spherical coordinates in the shadow coordinates system.

In the next step SP14, as shown in FIG. 15, the parallel light source position (r', α', β') obtained at the step SP13 is rotated about a Zs axis of the shadow coordinates system. That is, the parallel light source position obtained after it was rotated may be expressed as (r', 0, β'). In FIG. 13, a light source that was rotated by a rotation matrix Rz ($-\alpha'$) is expressed as a virtual parallel light source. When the position of the parallel light source 70 is rotated as described above, as shown in FIG. 13, the flux of light from a parallel light source 71 becomes parallel to a YsZs plane. The reason that the flux of light of the parallel light source 71 is rotated so as to become parallel to the YsZs plane as described above will be described below. When the object video signal V_1 is projected onto the XsYs plane of the shadow coordinates system by a perspective transform matrix P_{s0}'' at a step SP17 which will be described later on, if the flux of light of the incident light source is in parallel to the YsZs plane, then even

though the three-dimensional object video signal is projected onto the XsYs plane, the coordinates values of the Xs axis direction are not changed at all so that the perspective transform matrix P_{s0}'' which is used to project the object video signal onto the XsYs plane may be expressed very simply.

Specifically, since the rotation matrix $R_z(-\alpha')$ is the rotation matrix around the Zs axis, the rotation matrix $R_z(-\alpha')$ may be expressed as:

$$R_z(-\alpha') = \begin{bmatrix} \cos(-\alpha') & \sin(-\alpha') & 0 & 0 \\ -\sin(-\alpha') & \cos(-\alpha') & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \ldots (64)$$

At the steps SP11, SP12, SP13 and SP14, the transform processing for the parallel light source 70 is ended.

Then, the perspective transform matrix P_{PARA} used to generate the three-dimensional shadow video signal V_5 from the three-dimensional object video signal V_1 in the parallel light source mode using the parallel light source will be described with reference to FIG. 13B.

At a step SP15, similarly to the step SP11, the three-dimensional object video signal V_1 expressed by the world coordinates system is transformed into the shadow coordinates system by the transform matrix F^{-1}. The reason for this is that, similarly to the processing executed on the parallel light source described at the step SP11, a perspective transform matrix P_{s0}'', which will be described later on, is not the perspective transform matrix in the world coordinates system but the perspective transform

matrix in the shadow coordinates system. Thus, when the three-dimensional object video signal V_1 is projected onto the XsYs plane of the shadow coordinates system, respective pixel positions of the three-dimensional object video signal V_1 expressed by the world coordinates system should be transformed into the shadow coordinates system.

At a step SP16, the object video signal V_1 that was transformed into the shadow coordinates system at the step SP15 is rotated around the Z axis by $-\alpha'$(rad) by the rotation matrix $R_z(-\alpha')$. The reason for this will be described below. As shown in FIG. 15, since the position (r', α', β') of the parallel light source 70 is rotated around the Z axis by $-\alpha'$(rad) by the rotation matrix $R_z(-\alpha')$ at the step SP14, the object video signal V_1 should be rotated in response to the rotation processing of the parallel light source 70. Incidentally, as shown in FIG. 15, the three-dimensional object video signal that was rotated around the Zs axis by $-\alpha'$(rad) by the rotation matrix $R_z(-\alpha')$ is expressed as a virtual three-dimensional object video signal V_1''. Thus, a relative position relationship between the three-dimensional object video signal V_1 and the parallel light source 70 relative to an origin of the shadow coordinates system and a relative position relationship between the virtual three-dimensional object video signal V_1'' and the virtual parallel light source 71 relative to the origin of the shadow coordinates system are exactly the same.

At the next step SP17, by a perspective transform matrix

P_{s0}'', the virtual three-dimensional object video signal V_1'' is projected onto the XsYs plane of the shadow coordinates system. Initially, as shown in FIG. 15 and FIGS. 16A, 16B, a video signal which results from projecting the virtual object video signal V_1'' onto the XsYs plane by the perspective transform matrix P_{s0}'' is expressed as a virtual three-dimensional object video signal V_1''. FIG. 14A is a diagram showing in a three-dimensional fashion a position relationship between this virtual three-dimensional object video signal V_1'' and the virtual three-dimensional shadow video signal V_5''. FIG. 14B is a diagram showing a position relationship between the virtual three-dimensional object video signal V_1'' and the virtual three-dimensional shadow video signal V_5'' obtained when the YsZs plane is seen from the positive direction of the Xs axis. Here, assuming that (x_0, y_0, z_0) is a certain pixel point on the virtual object video signal V_1'' and (x_s, y_s, z_s) is a pixel point on the virtual shadow video signal V_5 which results from projecting this pixel (x_0, y_0, z_0) onto the XsYs plane by the perspective transform matrix P_{s0}'', then from a geometric relationship shown in FIG. 16B, the following relationship is established:

$$
\begin{aligned}
x_s &= x_0 \\
y_s &= y_0 + z_0 \cot\beta' \\
z_s &= 0
\end{aligned}
\qquad \ldots (65)
$$

Also, a relation among the point (x_0, y_0, z_0) on the virtual object video signal V_1'', the point (x_s, y_s, z_s) on the virtual shadow video

signal V_s and the perspective transform matrix P_{s0}'' may be expressed by the following equation:

$$[x_s\ y_s\ z_s\ 1] = [x_0\ y_0\ z_0\ 1] \cdot P_{s0}'' \qquad \text{... (66)}$$

Thus, from the equations (65) and (66), the perspective transform matrix may be expressed as:

$$P_{s0}'' = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & \cot\beta' & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \text{... (67)}$$

In the next step SP18, the virtual shadow video signal V_5'' is rotated around the Zs axis by the rotation matrix $R_z(\alpha')$. In FIG. 15, the rotated video signal is expressed as the three-dimensional shadow video signal V_5. A study of FIG. 15 reveals that the three-dimensional video signal V_5 is a video signal which results from projecting the three-dimensional object video signal V_1 onto the XsYs plane of the shadow coordinates system by the parallel light source 70. The reason that the virtual shadow video signal is rotated is that, since the three-dimensional object video signal V_1 is rotated by the rotation matrix $R_z(-\alpha')$ at the step SP16, the rotation movement processing done by the rotation matrix $R_z(-\alpha')$ should be returned to the original.

That is, since the rotation matrix $R_z(-\alpha')$ and the rotation matrix $R_z(\alpha')$ are set in an inverse matrix relationship, the rotation matrix $R_z(\alpha')$ may be expressed as:

$$R_z(\alpha') = \begin{bmatrix} \cos(\alpha') & \sin(\alpha') & 0 & 0 \\ -\sin(\alpha') & \cos(\alpha') & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \ldots (68)$$

In the next step SP19, by the transform matrix F shown in the equation (42), the three-dimensional shadow video signal V_5 expressed by the shadow coordinates system is transformed into the world coordinates system. Thus, it is possible to obtain the three-dimensional shadow video signal V_5 expressed by the coordinates values of the world coordinates system.

Having arranged the processing shown in the flowchart of FIG. 13B, it is to be understood that the processing for obtaining the three-dimensional object video signal V_5 of the world coordinates system from the three-dimensional object video signal V_1 of the world coordinates system comprises the step (SP15) for transforming the three-dimensional object video signal V_1 from the world coordinates system to the shadow coordinates system, the steps (SP16, SP17 and SP18) for generating the three-dimensional shadow video signal of the shadow coordinates system by projecting the three-dimensional object video signal onto the XsYs plane of the shadow coordinates system in the shadow coordinates system and the step (SP19) for obtaining the three-dimensional shadow video signal V_5 of the world coordinates system by transforming the three-dimensional shadow video signal of the shadow coordinates system from the shadow coordinates system to the world coordinates system.

Accordingly, since the perspective transform matrix P_{PARA} for obtaining the three-dimensional shadow video signal V_5 of

the world coordinates system from the three-dimensional object video signal V_1 of the world coordinates system may be expressed by multiplication of the transform matrix F^{-1}, the rotation matrix $R_z(-\alpha')$, the perspective transform matrix P_{s0}'', the rotation matrix $R_z(\alpha')$ and the transform matrix F^{-1}, it may be expressed by the following equation:

$$P_{PARA} = F^{-1} \cdot R_z(-\alpha') \cdot P_{s0}'' \cdot R_z(\alpha') \cdot F \quad \cdots (69)$$

Thus, substituting this transform matrix P_{PARA} into the equation (60), a transform matrix Tshadow″ for obtaining a two-dimensional shadow video signal V_4 from a two-dimensional source video signal in the parallel light source mode may be expressed as:

$$\begin{aligned} Tshadow'' &= T_0 \cdot P_{PARA} \cdot P_0 \\ &= T_0 \cdot F^{-1} \cdot R_z(-\alpha') \cdot P_{s0}'' \cdot R_z(\alpha') \cdot F \cdot P_0 \end{aligned} \quad \cdots (70)$$

Here, a calculation method for calculating a read address used to read out the two-dimensional shadow video signal V_6 from the frame memory 22 based on this transform matrix Tshadow″ is exactly the same as the calculation method for obtaining the read address (X_M, Y_M) used to read the two-dimensional object video signal V_2 from the frame memory 22 based on the matrix Tobj shown in the equation (3). That is, this calculation method is exactly the same calculations expressed from the equations (3) to (4).

Specifically, since this matrix Tshadow″ is the matrix

of 4 rows x 4 columns, similarly to the equation (4), a matrix, which results from removing the components (third row and third column) of the Z-axis direction from the above matrix is set to T_{33}shadow″ and respective parameters of an inverse matrix $(T_{33}\text{shadow}'')^{-1}$ of this transform matrix T_{33}shadow″ are set to the following equation:

$$(T_{33}\,shadow'')^{-1} = \begin{bmatrix} b_{11}'' & b_{12}'' & b_{13}'' \\ b_{21}'' & b_{22}'' & b_{23}'' \\ b_{31}'' & b_{32}'' & b_{33}'' \end{bmatrix} \qquad \cdots (71)$$

Also, the read address supplied from the read address generating circuit 24 of the shadow signal generating unit 20 is set to (X_M'', Y_M''). Referring to the calculation methods shown in the equations (3) to (14), this read address (X_M'', Y_M'') may be expressed by the following equation:

$$X_M'' = \frac{b_{11}''X_s + b_{21}''Y_s + b_{31}''}{b_{13}''X_s + b_{23}''Y_s + b_{33}''} \qquad \cdots (72)$$

$$Y_M'' = \frac{b_{12}''X_s + b_{22}''Y_s + b_{32}''}{b_{13}''X_s + b_{23}''Y_s + b_{33}''} \qquad \cdots (72')$$

where H_s' is expressed as:

$$H_s = b_{13}''\ X_s + b_{23}''\ Y_s + b_{33}''$$

Thus, the read address (X_M'', Y_M'') supplied to the frame memory 22 may be expressed by respective parameters (r_{11} to r_{33}, l_x, l_y, l_z and s) and the perspective value P_z serving as a previously-set parameter, the light source position (x_L, y_L, z_L), the rotation angles $(\theta_x, \theta_y, \theta_z)$ of the respective axes of the shadow coordinates system and the position $(x_{s0}, y_{s0}, z_{s0}$ of the origin of the shadow

coordinates system.

Accordingly, by supplying the screen address (X_s, Y_s) for effecting the addressing in response to the sequential order of the raster scanning of the monitor screen 3 to the equations (6) to (40), it is possible to sequentially calculate the read address (X_M'', Y_M'') on the frame memory 22 corresponding to the supplied screen address. Therefore, it is possible to generate the two-dimensional shadow video signal V_6 corresponding to the two-dimensional object video signal V_2.

(7) Description on the setting of shadow coordinates system:

As earlier noted, in order to set the shadow coordinates system for defining the shadow plane onto which the shadow of the object video signal is projected, it is necessary to set the respective rotation angles (θ_x, θ_y, θ_z) of the Xs axis, the Ys axis and the Zs axis of the shadow coordinates system for the X axis, the Y axis and the Z axis of the world coordinates system and the origin position (x_{s0}, y_{s0}, z_{s0}) of the shadow coordinates system relative to the origin of the world coordinates system. In the special effects apparatus according to the present invention, as mentioned before, the operator arbitrarily sets the respective rotation angles of the Xs axis, the Ys axis and the Zs axis of the shadow coordinates system and the origin of the shadow coordinates system. The rotation angles (θ_x, θ_y, θ_z) of the respective axes and the coordinates (x_{s0}, y_{s0}, z_{s0}) of the origin are substituted into the equations (42) and (47). However, if the operator sets a proper position as the origin of the shadow coordinates system as described

above, then as shown in FIG. 15A, it is frequently observed that the three-dimensionally-transformed object video signal V_1 and the three-dimensional shadow video signal V_5 are spaced apart from each other spatially. The reason for this is that the three-dimensional object video signal V_1 does not exist on the shadow plane, in other words, the shadow plane cannot be set in such a manner that the three-dimensional object video signal V_1 may exist on the shadow plane. Of course, if the operator desires the shadow plane shown in FIG. 17A, then there occurs no trouble. However, in order to obtain the effect in which a shadow is added to a certain object existing on the ground surface by light from a light source, it is necessary to set this ground surface as a shadow plane on to which the shadow is projected. That is, the origin of the shadow coordinates system must be set in such as manner that the three-dimensional object video signal V_1 spatially exists on the shadow plane. To this end, the special effects apparatus according to the present invention includes an origin setting mode for automatically setting the origin of the shadow coordinates system.

In this origin setting mode, initially, the operator designates a certain point on the source video signal V_0. This designated point is transformed by the three-dimensional transform matrix T_0 on the three-dimensional space, and a corresponding point on the object video signal Vobj transformed on the three-dimensional space is set to the origin of the shadow coordinates system. Thus, the origin of the shadow coordinates system is set on the point on the three-dimensional object video signal Vobj so that the

three-dimensional object video signal Vobj exists on the shadow plane.

Specifically, as shown in FIG. 17B, let it be assumed that a is an upper right point of the source video signal V_0, b is an upper left point, c is a lower left point and d is a lower right point. Also, let it be assumed that a′, b′, c′ and d′ represent corresponding points of the three-dimensional object video signal Vobj. Further, let it be assumed that $(x_a, y_a, 0)$, $(x_b, y_b, 0)$, $(x_c, y_c, 0)$ and $(x_d, y_d, 0)$ are four points of the source video signal V_0 and that (x_a', y_a', z_a'), (x_b', y_b', z_b'), (x_c', y_c', z_c') and (x_d', y_d', z_d') are respective coordinates of the points a′, b′, c′ and d′ of the three-dimensional object video signal Vobj.

Then, a case in which the operator designates the point d on the source video signal V_0 will be described by way of example. A corresponding point on the object video signal Vobj and which results from transforming the point d $(x_d, y_d, 0)$ on the source video signal V_0 designated by the operator by the three-dimensional transform matrix T_0 is d′ (x_d', y_d', z_d'). Here, since the point d $(x_d, y_d, 0)$ and the point d′ (x_d', y_d', z_d') are respectively expressed by vectors of homogeneous coordinates system as a vector $[x_d\ y_d\ 0\ 1]$ and a vector $[x_d'\ y_d'\ z_d'\ 1]$, a relationship among these vectors and the three-dimensional transform matrix T_0 may be expressed by the following equation:

$$[x_d'\ y_d'\ z_d'\ 1] = [x_d\ y_d\ 0\ 1] \cdot T_0$$

$$= [x_d \ y_d \ 0 \ 1] \begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ 1_x & 1_y & 1_z & s \end{bmatrix} \quad \ldots (73)$$

Thus, this equation (73) can yield the following equation:

$$x_d' = (r_{11}x_d + r_{21}y_d + 1_x)/s$$

$$y_d' = (r_{12}x_d + r_{22}y_d + 1_y)/s$$

$$z_d' = (r_{13}x_d + r_{23}y_d + 1_z)/s \quad \ldots (74)$$

Thus, by substituting (x_d', y_d', z_d') obtained in the equation (74) into the origin (x_{s0}, y_{s0}, z_{s0}) of the shadow coordinates system serving as the parameter of the movement matrix L shown in the equations (42) and (47), the origin of the shadow coordinates system is set on the point on the three-dimensional object video signal V_1. That is, the shadow coordinates system is set in the three-dimensional space such that the three-dimensional object video signal V_1 may exist on the shadow plane. Thus, the special effects apparatus according to the present invention may provide a natural effect such that a shadow of an object existing on the ground may be projected onto the ground surface by light from the sun.

(8) Description of a real shadow generator 50:

A real shadow key generator 50 into which the shadow key signal (K_4 in the point source mode and k_6 in the parallel light source mode) inputted and from which a real shadow relative to this key signal, i.e. real shadow key signal (K_4' in the point source mode and K_6' in the parallel light source mode) for generating and

outputting light and shade and gradation is outputted will be described with reference to FIG. 18.

The real shadow generator 50 generally comprises a gain control circuit 500, a horizontal LPF 501, a vertical LPF and a real shadow control unit 503. Also, the real shadow control unit 503 is comprised of a ROM 504 which stores table data indicative of a gain characteristic of the gain control circuit 500 and filtering characteristics of the horizontal and vertical LPFs 501, 502 which will be described later on.

The gain control circuit 500 is a circuit for controlling a gain supplied to the shadow key signal (K_4, K_6) supplied from the frame memory 23. The horizontal LPF 501 is a low-pass filter (LPF) for filtering out a horizontal direction frequency component of the shadow key signal (K_4, K_6) from the gain control circuit 500. The vertical LPF 502 is a low-pass filter for filtering out a vertical direction frequency component of the shadow key signal (K_4, K_6) from the horizontal LPF 501. The real shadow control unit 503 controls the gain control circuit 500 and the horizontal and vertical LPFs 501, 502 based on a predetermined gain characteristic and filtering characteristic stored in the ROM 504 to which a parameter H, used as depth information in this embodiment, from the read address generating circuit 24 is inputted. Here, the predetermined gain characteristic is data which becomes a resultant intended gain characteristic, and the filtering characteristic is data which becomes a resultant intended filtering characteristic.

An image which is finally obtained in this embodiment

is such an image in which the more the shadow S for the object O becomes distant from the object O the more the shadow S becomes light and blurred as shown in FIG. 19(A). Incidentally, although the gradation of this shadow is not changed smoothly for the sake of making a drawing, the gradation is changed very smoothly in actual practice.

A gain characteristic (GAIN) which indicates the light and shade of this shadow S is illustrated in FIG. 19(B). As shown in FIG. 19B, as the parameter that is used as the depth information increases, a gain relative to the shadow key signal (K_4, K_6) is decreased. Further, as the parameter H decreases, the gain relative to the shadow key signal (K_4, K_6) is increased. That is, the more the shadow S becomes distant the more the brightness is lowered. Thus, the characteristic is presented as shown in FIG. 19(B). Table data comprising the parameter H and the gain data is stored in the ROM 504 disposed within the real shadow control unit 503 shown in FIG. 18.

Also a gradation amount (softness) of the shadow S, i.e. filtering characteristic (FILTER) of the low-pass filter is presented as shown in FIG. 19(C). As shown in FIG. 19(C), as the parameter H_s increases, the respective low pass bands of the horizontal and vertical low-pass filters 501 and 502 are narrowed. Further, as the parameter H_s decreases, the respective low pass bands of the horizontal and vertical low-pass filters 501, 502 become flat, i.e. wide. That is, the more the shadow S becomes distant from the object O, the more the contour or the like of the shadow

S becomes faded out. Table data comprising the parameter H_s and filter coefficient data in which the pass band is variable and which becomes a characteristic shown in FIG. 19(C) is stored in the ROM 504 of the real shadow control unit shown in FIG. 18 as mentioned before. One kind of the characteristic data shown in FIG. 19(C) is used for the horizontal and vertical low-pass filters 501, 502 shown in FIG. 18. The horizontal low-pass filter 501 is used because a high frequency component cannot pass in the horizontal direction. Therefore, the less the high frequency component becomes the more the contour or the like becomes faded out. This is also true in the vertical direction.

(9) Description of combiner 30:

Next, the combiner 30 will be described with reference to FIG. 20. Prior to the description of the combiner , a general synthesis theory of the combiner 30 will be described.

The manner in which two video signals V_A and V_B are synthesized on the basis of the key signals K_A and K_B in accordance with an order of priority determined by depth information H_{OA} will be described. A synthesis equation executed when the second video signal V_B has a priority (near the screen) over the first video signal V_A is expressed as:

$$V_{A(OUT)} = K_A V_A + (1 - K_A) K_B V_B \qquad \ldots (75)$$

Thus, there is obtained a synthesized output expressed as $V_{O(OUT)}$.

Similarly, a synthesis equation executed when the first video signal V_A has a priority over the second video signal V_B is expressed as:

$$V_{B(OUT)} = K_B\ V_B + (1 - K_B)\ K_A\ V_A \qquad \ldots (76)$$

Thus, there is obtained a synthesized output expressed as $V_{B(OUT)}$.

When the second video signal V_B has a priority (near the screen) over the first video signal V_A, considering a priority signal H_{OA} relative to the synthesized video signal $V_{A(OUT)}$, a synthesized video signal relative to the first video signal V_A may be expressed by the following equation:

$$V_{A(OUT)X} = V_{A(OUT)}H_{OA} \qquad \ldots (77)$$

Substituting the equation (75) into the equation (77), we have:

$$V_{A(OUT)X} = \{K_AV_A + (1-K_A)\ K_BV_B\}\ H_{OA} \qquad \ldots (78)$$

A priority signal obtained when the first video signal V_A has a priority over the second video signal V_B may be expressed as $(1 - H_{OA})$ by using the priority signal H_{OA}. Accordingly, when the first video signal V_A has the priority over the second video signal V_B, considering the priority signal $(1 - H_{OA})$ relative to $V_{A(OUT)}$, the output V_B may be expressed by the following equation:

$$V_{B(OUT)X} = V_{B(OUT)}\ (1 - H_{OA}) \qquad \ldots (79)$$

Substituting this equation into the equation (32), we have:

$$V_{B(OUT)X} = \{K_B\ V_B + (1 - K_B)\ K_A\ V_A\}\ (1 - H_{OA}) \qquad \ldots (80)$$

Accordingly, if the final synthesized video output V_{OUT} is processed in a keying fashion by a synthesized key signal K_{OU} expressed as:

$$V_{OUT}\ K_{OUT} = V_{A(OUT)X} + V_{B(OUT)X} \qquad \ldots (81)$$

The final synthesized video output V_{OUT} is expressed by the following equation:

$$V_{OUT} = \frac{V_{A(OUT).X} + V_{B(OUT).X}}{K_{OUT}} \quad \ldots (82)$$

Since the area (area in which neither the video signal V_A nor the video signal V_B is displayed) other than the areas in which images corresponding to the first and second video signals V_A and V_B are displayed may be defined in the form of a product of $(1 - K_A)(1 - K_B)$ by using the key signals K_A and K_B of the first and second video signals V_A and V_B, a key signal K_{OUT} concerning the area in which the video signal V_A or V_B is displayed) may be expressed by the following equation:

$$K_{OUT} = 1 - (1 - K_A)(1 - K_B) \quad \ldots (83)$$

Accordingly, substituting the equations (78), (80) and (83) into the equation (77), the final synthesized video output V_{OUT} is expressed as:

$$\begin{aligned} V_{OUT} = (\{K_A V_A + (1-K_A) K_B V_B\} \; H_{OA} \\ + \{K_B V_B + (1-K_B) K_A V_A\} \; (1-H_{OA}) \\ x \frac{1}{1-(1-K_A)\;(1-K_B)} \\ = (\{H_{OA} K_A + (1-H_{OA})\;(1-K_B)\; K_A\} V_A \\ + \{(1-H_{OA}) K_B + H_{OA}(1-K_A) K_B\} V_B \\ x \frac{1}{1 - (1-K_A)\;(1-K_B)} \end{aligned}$$

$$\ldots (84)$$

Thus, the key signal K_{OUT} and the synthesized video output V_{OUT} expressed by the equations (83) and (84) are outputted from the combiner 30 as a mixed key signal K'_{mix} and a mixed video signal V'_{mix}.

The combiner 22 of the special effects apparatus

according to the present invention effects a keying processing on two image information, i.e. video signals of two images obliquely extended to cross to each other with the depth information H_o and H_s in an XTZ space behind the screen surface 3A shown in FIG. 20(A), i.e. the object video signal V_2 and the shadow video signal (V_1 in the point source mode and V_6 in the parallel light source mode) based on the key signal K_2 (FIG. 20(B)) and K_4 (K_4 in the point source mode and K_6 in the parallel light source mode) (FIG. 20(C)) and synthesizes the object video signal and the shadow video signal by the arrangement of FIG. 2 based on the priority signals H_{OA} and $(1-H_{OA})$ (FIGS. 20(D) and 20(E)) of the respective portions of the two images.

Here, the priority signal H_{OA} is information indicating a display priority relative to the shadow video signal (V_4 or V_6) of the object video signal V_2. When $H_{OA} = 1$, for example, if the priority of the object video signal V_2 is 100%, then the shadow video signal (V_4 or V_6) is not displayed at all. That is, it is to be noted that the object video signal V_2 is opaque. When $H_{OA} = 0.5$, the object video signal V_2 is semitransparent so that the shadow video signal V_2 is displayed transparent. That is, since 50% of the object video signal V_2 is displayed and 50% of the shadow video signal (V_4 or V_6) is displayed, there is displayed a video signal in which the object video signal V_2 and the shadow video signal (V_4 or V_6) is mixed together.

FIG. 21 shows an overall arrangement of the combiner 30. As illustrated, the combiner 30 comprises a first video signal

synthesizing unit 41 for computing a synthesizing ratio of the object video signal V_2, a second video signal synthesizing unit 42 for computing a synthesizing ratio of the shadow video signal (V_4 or V_6), a key signal synthesizing unit 43 for forming key signals for the object video signal V_2 and the shadow video signal (V_4 or V_6), a synthesizing output unit 44 for synthesizing the object video signal V_2 and the shadow video signal (V_4 or V_6) and a priority signal generating circuit 48.

The first video signal synthesizing unit 41 comprises a "1" coefficient circuit 49, a "$1-K'_4$" (or $1-K'_6$)" coefficient circuit 50 and multiplying circuits 46. 47.

The synthesizing circuit 45 outputs output data D4 based on first, second and third input data D1, D2 and D3 by executing the following equation:

$$D4 = D1 \times D2 + (1 - D1) \times D3 \qquad \ldots (85)$$

As the data D1, D2 and D3 inputted in actual practice, there are inputted the priority signal H_{OA} outputted from the priority signal generating circuit, the "1" output from the "1" coefficient circuit and the "$1-K'_4$ (or $1-K'_6$)" from the "$1-K'_4$ (or $1-K'_6$)" coefficient circuit 50. Therefore, the output data D4 outputted from the synthesizing circuit 45 becomes $\{H_{OA} + (1 - H_{OA}) \cdot (1 - K'_4 \text{ (or } K'_6))\}$. Further, this output data D4 is supplied to the multiplying circuits 46 and 47 and the multiplying circuit 46 generates an output $D4 \times K_2$ by multiplying the output data D4 and the object key signal K_2 inputted to the combiner 30. Furthermore, the output $D4 \times K_2$ and the object video signal V_2 are inputted to the multiplying

circuit 47, from which there is obtained an output D4 x K_2 x V_2. Accordingly, an output data S11 outputted from the first video signal synthesizing unit 41 is expressed by the following equation:

$$S11 = \{H_{OA} + (1 - H_{OA}) \cdot (1 - K'_4 \text{ (or } K'_6))\}$$

$$K_2 \cdot V_2 \qquad \ldots (86)$$

Also, the second video signal synthesizing unit 43 comprises a "1 - H_{OA}" coefficient circuit 52, a "1" coefficient circuit 53, a "1 - K_2" coefficient circuit 54, a synthesizing circuit 51 for executing the same computation as the equation (75) and multiplying circuits 152 and 153.

The input data D1, D2 and D3 inputted to the synthesizing circuit 51 are respectively the "1 - H_{OA}" output from the "1 - H_{OA}" coefficient circuit 51, the "1" output from the "1" coefficient circuit and the "1 - K_2" output from the "1 - K_2" coefficient circuit 54, the output data D4 outputted from the synthesizing circuit 51 becomes $\{(1 - H_{OA}) + H_{OA} \cdot (1 - K_2)\}$.

Accordingly, synthesized output data S12 of the second video signal synthesizing unit 43 is expressed as:

$$S12 = \{(1 - H_{OA}) + H_{OA} \cdot (1 - K_2)\}\ K'_4 \text{ (or } K'_6) \cdot V_4.$$

Also, the key signal synthesizing unit 43 comprises a multiplying circuit 55 and a "$1 - (1 - K_2) \cdot (1 - K'_4$ (or K'_6))" computation circuit 56. The multiplying circuit 55 multiplies a "(1 - K'_4 (or K'_6)) output from the "(1 - K'_4 (or K'_6)) coefficient circuit 50 and a "(1 - K_2) output from the "(1 - K_2)" coefficient circuit 54 and outputs "$(1 - K_2) \cdot (1 - K'_4$ (or K'_6))". The "1 -

$(1 - K_2) \cdot (1 - K'_4$ (or K'_6))" computation circuit 56 is supplied with "$(1 - K_2) \cdot (1 - K'_4$ (or K'_6))" output and outputs its output as a key signal K_0 expressed by the following equation:

$$K_{OA} = 1 - (1 - K_2) \cdot (1 - K'_4 \text{ (or } K'_6)) \quad \ldots (88)$$

The key signal K_0 expressed by this equation (78) is outputted to the mixer 40 of the next stage as the output signal from the combiner 30.

Also, the synthesizing unit 44 supplies the output "1 - $(1 - K_2) \cdot (1 - K'_4$ (or K'_6), which was transformed into a fraction by an inverse circuit 57, to a multiplying circuit 58, in which it is multiplied with an added output from the adding circuit 59 and outputted from the combiner 30 to the mixer 40 as a synthesized video signal V_0.

The adding circuit 59 is supplied with the synthesized output data S11 and S12 from the first and second video signal synthesizing units 41 and 42, and hence the synthesized video signal V_0 becomes a value expressed by the following equation:

$$V_0 = (\{H_{OA}K_2 + (1 - H_{OA}) \cdot (1 - K'_4 \text{ (or } K'_6))\}\ K_2 \cdot V_2 + (1 - H_{OA})K'_4 \text{ (or } K'_6) + H_{OA} \cdot (1 - K_2)K'_4 \text{ (or } K'_6)\} \cdot V_4 \text{ (or } V_6)) \times 1/(1 - K_2) \cdot (1 - K'_4 \text{ (or } K'_6))\} \quad \ldots (89)$$

Accordingly, a mixed video signal V'_{mix} (V''_{mix} in the parallel light source mode) and a mixed key signal K'_{mix} (K''_{mix} in

the parallel light source mode) that are outputted from the combiner 30 in actual practice are expressed by the equations (89), (88), respectively.

The equation of the synthesized video output on the equation (87) thus obtained theoretically is the same as the synthesized video output V_{OA} of the equation (89) obtained in the combiner 31 of FIG. 21. Thus, it is to be noted that the combiner 30 executes the synthesis theory of the equations (75) to (84).

In the combiner 30 of FIG. 21, as shown in FIG. 20(A), when the images O and A having the width information H_0 and H_S cross to each other, the video signals V_2 and V_4 (or V_6) are processed in a keying fashion by the key signals K_2 and K'_4 (or K'_6).

The depth information H_0 of the image O causes the priority signal generating circuit 48 to generate a priority signal H_{OA} (FIG. 20D) which outputs the object video signal V_2 in the ranges W2 and W4 in which the image has the depth information H_0 close to the screen surface 3A rather than the image A.

On the other hand, a priority signal $(1 - H_{OA})$ used to output the shadow video signal V_4 (or V_6) in the ranges W1 and W3 in which the image A has the depth information H_S close to the screen surface 3A rather than the image O is obtained as $(1 - H_{OA})$ (FIG. 20(E)).

Thus, as the synthesized video signal V_0 from the combiner 30, as shown in FIG. 20(G), in the ranges W2 and W4 of the object image O with a high priority order, the object image O is displayed on the screen 3A. Also, in the ranges W1 and W3 of

the shadow image A in which the priority order of the depth information H_S is high, the shadow image A is displayed on the screen 3A.

Then, this priority signal will be described next. In the case of this embodiment, in the priority signal generating circuit 48, as shown in FIG. 22, a subtracting circuit 65 receives the depth information H_0 and H_S (FIG. 23(A)) of the inputted object video signal V_2 and the shadow video signal V_4 (or V_6) and its subtracted output S21 (= H_0 - H_S) is multiplied with a gain signal S22 (= G) supplied from a gain register 67 in the multiplying circuit 66. Thereafter, its multiplied output S23 (= (H_0 - H_S) G) (FIG. 23(B)) is supplied to a limiter 68.

Here, the gain signal S22 (= G) has a function to change an inclination (i.e. changing ratio of synthesized depth ratio) of the subtracted output (H_0 - H_S) as shown in FIG. 22(B).

The limiter 68 is adapted to limit the value of the multiplied output S23 to the range of from +0.5 to -0.5 as shown in FIG. 23(C). Thus, when the level becomes -0.5 or -0.5 in a range in which a difference of depth information is large and the difference of the depth information range from +0.5 to -0.5, the limiter output S24 presents a value of (H_0 - H_A).

The limiter output S24 is supplied to and added with an offset signal S25 (= L_0) from an offset register 70 by an adding circuit 69. Its added output is outputted from the priority signal generating circuit 48 as the priority signal H_{OA} whose value is switched in a range of from 1 to 0 as shown in FIG. 22(D).

In the priority signal generating circuit 48 in FIG. 22, when both of the first and second images O and A cross to each other, in a range W23 (FIG. 23(D)) near the crossing point, the priority signal H_{OA} is changed in accordance with a magnitude of a difference between the depth information H_o and H_s of the first and second images O and A.

Accordingly, in the range W23 near the crossing point, the priority signal H_{OA} is not rapidly switched to 1 to 0 (or 0 to 1) so that the image within the range W23 near the crossing point becomes transparent so as to overlap the images O and A (FIG. 20(G)). That is, since the images O and A are displayed in a mixed state, a mixing ratio of the images O and A is gently changed near the portion in which the images O and A cross to each other, thereby making it possible to display an image without a sense of incongruity.

Thus, there may be achieved the effect on the special effects image in which the image O and A are changed softly in the range W23 near the point at which the first and second images O and A cross to each other. In addition, the manner in which the width and the image of the boundary area are changed may be adjusted by changing the value of the gain output S22 of the gain register 67 to the extent that the operator needs the adjustment.

The combiner 22 includes a depth information synthesizing circuit of a NAM mix circuit arrangement. The depth information synthesizing circuit selects depth information (representing the position of the image near the screen surface

3A) of the images O and a and transmits the selected depth information from the combiner 22 as synthesized depth information H_0/H_S.

The mixed video signal (V'_{mix} in the point source mode and V''_{mix} in the parallel light source mode) and the mixed key signal (K'_{mix} in the point source mode and K''_{mix} in the parallel light source mode) outputted from the combiner 30 are expressed by the above-mentioned equations (89) and (88). The mixer 40 mixes the inputted mixed video signal, the inputted mixed key signal and the background signal V'_{BK}, and finally outputs an output video signal V'_{OUT}. Accordingly, the output video signal V'_{OUT} outputted from the mixer 40 is obtained by substituting the equations (88) and (89) into the equations (C) and (D). That is, in the point source mode, the output video signal is expressed as:

$$\begin{aligned} V'_{OUT} &= K'_{mix}\ V'_{mix} + (1 - K'_{mix})\ V_{BX} \\ &= \{H_{OA}K_2 + (1 - H_{OA})\ (1 - K'_4)\ K_2\}\ V_2 \\ &+ \{(1 - H_{OA})\ K'_4 + H_{OA}\ (1 - K_2)\ K'_4\}\ V_2 \\ &+ (1 - K'_4)\ (1 - K_2)\ V_{BK} \qquad \ldots (90) \end{aligned}$$

Also, the output video signal V''_{OUT} obtained in the parallel light source mode is expressed as:

$$\begin{aligned} V''_{OUT} &= K''_{mix}\ V''_{mix} + (1 - K''_{mix})\ V_{BX} \\ &= \{H_{OA}K_2 + (1 - H_{OA})\ (1 - K'_6)\ K_2\}\ V_2 \\ &+ \{(1 - H_{OA})\ K'_6 + H_{OA}(1 - K_2)K'_6\}\ V_2 \\ &+ (1 - K'_6)\ (1 - K_2)\ V_{BX} \qquad \ldots (91) \end{aligned}$$

Here, the gain of the real shadow key signal (K'_4 in the point source mode and K'_6 in the parallel light source mode)

outputted from the real shadow generator 50 is controlled so that $K'_4 = 0$ in the point source mode and $K'_6 = 0$ in the parallel light source mode. Therefore, the equations (90) and (91) are respectively modified as:

$$V'_{OUT} = \{H_{OA}K_2 + (1 - H_{OA})\ K_2\}\ V_2 + (1 - K_2)\ V_{BK}$$

$$= K_2\ V_2 + (1 - K_2)\ V_{BK} \qquad \ldots (92)$$

$$V''_{OUT} = \{H_{OA}K_2 + (1 - H_{OA})\ K_2\}\ V_2 + (1 - K_2)\ V_{BK}$$

$$= K_2\ V_2 + (1 - K_2)\ V_{BK} \qquad \ldots (93)$$

In this case, from the above-mentioned equations (92) and (93), the output video signals in the point source mode and the parallel light source mode are represented as $(1 - K_2)\ V_{BK}$ except the portion of $K_2\ V_2$. Thus, when the gain of the real shadow key signal is low, then there is outputted the background signal V_{BK} of approximately 100%.

Also, since $K'_4 = 1$ is established in the point source mode and $K'_6 = 1$ is established in the parallel light source mode when the real shadow generator 50 output the real shadow key signal whose gain is 100%, the equations (90) and (91) are respectively modified as:

$$V'_{OUT} = H_{OA}K_2V_2 + \{(1 - H_{OA}) + H_{OA}(1 - K_2)\}\ V_4$$

$$= H_{OA}K_2V_2 + (1 - H_{OA}K_2)\ V_4 \qquad \ldots (94)$$

$$V''_{OUT} = H_{OA}K_2V_2 + \{(1 - H_{OA}) + H_{OA}(1 - K_2)\}\ V_6$$

$$= H_{OA}K_2V_2 + (1 - H_{OA}K_2)\ V_6 \qquad \ldots (95)$$

In this case, both in the point source mode and the parallel light

source mode, at other portions than $H_{0AX} K V_2$, there is outputted the shadow video signal (V_4 or V_6) of 100%. Since it is customary that the shadow video signal is displayed black on the screen, in this case, the shadow video signal becomes deep black and displayed on the screen of the monitor.

(10) Description of operation and effects of special effects apparatus:

Then, an operation of this special effect apparatus will be described in brief.

Initially, the operator enters respective parameters necessary for computing read addresses used in the special effect apparatus by operating a suitable device such as a three-dimensional pointing device or key provided on the control panel 5. Here, the parameters necessary for computing the read addresses are a perspective value P_z, respective rotation angles (θ_x, θ_Y, θ_z) of the Xs axis, the Ys axis and the Zs axis of the shadow coordinates system, origins (x_{so}, y_{so}, z_{so}) of the shadow coordinates system, kinds of light source indicative of the parallel light source or the point light source and a position (x_L, y_L, z_L) or (γ, α, β) or the like. Also, when there is designated a mode in which the origins of the shadow coordinates system are set automatically, data indicative of one of points (a to d) of the four corners of the source video signal is inputted from the control panel 5.

Initially, the manner in which the special effects apparatus is operated when the point light source is designated as the kind of the light source will be described.

The CPU 8 receives these parameters entered from the control panel 5 and reflect these received parameters on the computation of the read address in real time. Specifically, the CPU 8 monitors the change of the parameters supplied from the control panel 5 at the frame period, and computes parameters (b_{11} to b_{33}, b_{11}' to b_{33}') that are used to compute the read address based on the supplied parameters. Thus, these parameters may be varied in real time at the frame period in response to the operation of the operator, and the read address is computed in real time in response to the parameters thus varied. Also, the CPU 8 may store these parameters in the RAM 7 at every frame as set values. Incidentally, in this stage, since the operator does not instruct a three-dimensional image transform on the source video signal V_0, the source video signal V_0 is displayed on the monitor screen 3.

Then, the operator instructs the three-dimensional image transform operation on the source video signal V_0 by operating the three-dimensional pointing device or the like disposed on the control panel 5. When the operator instructs the three-dimensional image transform, the CPU 8 receives r_{11} to r_{33}, ℓ_X, ℓ_Y, ℓ_Z and s which are respective parameters of the three-dimensional image transform designated by the operator from the control panel 5, and reflect these parameters on the computation of the read address in real time. Specifically, the CPU 8 monitors the change of these parameters supplied from the control panel 5 at the frame period, and also computes at the frame period parameters (b_{11} to b_{33}, b_{11}' to b_{33}') used to compute the read address based on the supplied

parameters. Then, the CPU 8 computes the respective parameters b_{11} to b_{33} of a three-dimensional transform matrix T_{33}^{-1} expressed by the equation (8) based on the received parameters r_{11} to r_{33}, ℓ_X, ℓ_Y, ℓ_Z and s. Specifically, it is possible to obtain the parameters b_{11} to b_{33} by substituting the parameters r_{11} to r_{33}, ℓ_X, ℓ_Y, ℓ_Z and s into the equations (28) to (37). Also, the CPU 8 receives the received parameters r_{11} to r_{33}, ℓ_X, ℓ_Y, ℓ_Z, s of the three-dimensional transform matrix T_0, the parameters θ_X, θ_Y, θ_Z, x_{S0}, y_{S0}, z_{S0} concerning the shadow coordinates and the parameters x_L, y_L, z_L concerning the light sources, and computes the respective parameters b_{11}' to b_{33}' of the three-dimensional transform matrix $(T_{33}shadow')^{-1}$ expressed on the equation (57). The CPU 8 supplies the thus computed parameters b_{11} to b_{33} to the read address generating circuit 14 of the object signal generating unit 10, and supplies the computed parameters b_{11}' to b_{33}' to the read address generating circuit 24 of the shadow signal generating unit 20.

The read address generating circuit 14 in the object signal generating unit 10 receives the parameters b_{11} to b_{33} from the CPU 8, receives the screen address (X_S, Y_S) from the screen address generating circuit 9, and generates the object signal read address (X_M, Y_M) at the frame period based on the equations (13) and (14). The thus generated read address (X_M, Y_M) is respectively supplied to the video signal frame memory 12 and the key signal frame memory 14. As a result, the object video signal V_2 is outputted from the frame memory 12 and the object key signal K_2 is outputted

from the frame memory 13.

On the other hand, the read address generating circuit 24 in the shadow signal generating unit 20 receives the parameter b_{11}' to b_{33}' from the CPU 8, also receives the screen address (X_S, Y_S) from the screen address generating circuit 9, and generates the shadow signal read address (X_H', Y_H') based on the equations (58) and (59) at the frame period. The thus generated read address (X_H', Y_H') are respectively supplied to the video signal frame memory 22 and the key signal frame memory 23. As a result, as shown in FIG. 7B, the shadow video signal V_4 is outputted from the frame memory 22, and the shadow key signal K_4 is outputted from the frame memory 23. In the real shadow generator 50 into which the shadow key signal K_4 outputted from the frame memory 23 is inputted, the real shadow control unit 503 reads out corresponding gain data from the table 1 comprising the parameter H_S and the gain data from the ROM 504 based on the parameter H_S, and supplies the gain data to the gain control circuit 500. Accordingly, the gain control circuit 500 supplies a gain corresponding to the gain data supplied from the real shadow control unit 503 to the inputted shadow key signal K_4. The real shadow control unit repeats the above-mentioned processing.

The shadow key signal outputted from the gain control circuit 500 is inputted to the horizontal LPF 501 and the vertical LPF 502. The real shadow control unit 503 reads out corresponding coefficient data from a table (see FIG. 19C) comprising H_S stored in the ROM 504 and filter coefficient data based on the value of

inputted H_s used as the depth information in this embodiment, and supplies this filter coefficient data to the horizontal LPF 501. The horizontal LPF 501 multiplies the inputted shadow key signal with the filter coefficient data from the real shadow control unit 503, and outputs a multiplied result. Then, the real shadow control unit 503 reads out corresponding coefficient data from the table (see FIG. 19C) comprising H_s stored in the ROM 504 of the real shadow control unit 503 and filter coefficient data based on inputted H_s, and supplied the thus read-out filter coefficient data to the vertical LPF 502. The vertical LPF 5-2 multiplies the shadow key signal from the horizontal LPF 501 with the filter coefficient data read out from the real shadow control unit 503, and outputs a multiplied result as the real shadow key signal K'_4 that is finally outputted from the real shadow generator 50. Accordingly, as shown in FIG. 19A, the contour of the shadow S near the object O becomes clear because the multiplied filter coefficient data near the object O becomes large. Then, as the shadow comes away from the object O, the value of the multiplied filter coefficient data decreases so hat the contour of the data of the shadow S becomes unclear (blurred) progressively.

Although the manner in which the contour becomes unclear progressively cannot be illustrated for the sake of drawings, in actual practice, the shadow becomes unclear progressively as the shadow comes away from the object.

The combiner 30 receives the object video signal V_2 and the object key signal K_2 from the object signal generating unit 10,

receives the shadow video signal V_4 and the real shadow key signal K_4' from the shadow signal generating unit 20, and generates the mixed video signal V_{mix}' and the mixed key signal K_{mix}' on the basis of the equation (a). The mixer 40 receives the background video signal V_{BK} supplied from the outside, the mixed video signal V_{mix} and the mixed key signal K_{mix}' outputted from the combiner 30, and generates an output video signal V_{OUT}' on the basis of the equation (c).

Next, the manner in which the special effects apparatus is operated when the parallel light source is designated as the light source will be described.

Initially, the CPU 8 receives from the control panel 5 the parameters (θ_X, θ_Y, θ_Z) concerning the respective axes of the shadow coordinates, the parameters (x_{S0}, y_{S0}, z_{S0}) concerning the origin of the shadow coordinates and the parameters (γ, α, β) concerning the parallel light source. Also, on the basis of the operation state of the three-dimensional pointing device provided on the control panel 5, the CPU 8 receives from the control panel 5 the parameters γ_{11} to γ_{33}, ℓ_X, ℓ_Y, ℓ_Z, s of the three-dimensional transform matrix T_0. The CPU 8 monitors in real time the changes of these parameters supplied from the control panel 5 at the frame period, and computes at the frame period the parameters (b_{11} to b_{33}, b_{11}'' to b_{33}'') used to compute the read address based on the supplied parameters. Thus, these parameters may be varied in real time at the frame period in response to the operation of the operator. Then, the read address is computed in real time in response to the varied

parameters.

Then, the CPU 8 computes the respective parameters b_{11} to b_{33} of the three-dimensional transform matrix T_{33}^{-1} expressed by the equation (8) based on the received parameters γ_{11} to $\gamma 33$, ℓ_X, ℓ_Y, ℓ_Z and s. Specifically, it is possible to obtain the parameters b_{11} to b_{33} by substituting the parameters γ_{11} to $\gamma 33$, ℓ_X, ℓ_Y, ℓ_Z and s into the equations (28) to (37). Also, the CPU 8 receives the parameters γ_{11} to $\gamma 33$, ℓ_X, ℓ_Y, ℓ_Z and s of the received three-dimensional transform matrix T_0, the parameters θ_X, θ_Y, θ_Z, x_{s0}, y_{s0}, z_{s0} concerning the shadow coordinates and the parameters γ, α, β concerning the light source, and computes the respective parameters b_{11}'' to b_{33}'' of the three-dimensional transform matrix (T_{33}shadow$''$) expressed on the equation (71) based on these parameters. The CPU 8 supplies the thus computed parameters b_{11} to b_{33} to the read address generating circuit 14 of the object signal generating circuit 10, and also supplies the thus computed parameters b_{11}'' to b_{33}'' to the read address generating circuit 24 of the shadow signal generating circuit 20.

The read address generating circuit 14 in the object signal generating unit 10 receives the parameters b_{11} to b_{33} from the CPU 8, receives the screen address (X_S, Y_S) from the screen address generating circuit 9, and generates the object signal read address (X_M, Y_M) at the frame period on the basis of the equations (13) and (14). The thus generated read address (X_M, Y_M) is supplied to the video signal frame memory 12 and the key signal frame memory

13, respectively. As a result, the object video signal V_2 is outputted from the frame memory 12 and the object key signal K_2 is outputted from the frame memory 13.

On the other hand, the read address generating circuit 24 in the shadow signal generating unit 20 receives the parameters b_{11}'' to b_{33}'' from the CPU 8, receives the screen address (X_S, Y_S) from the screen address generating circuit 9, and generates a shadow signal read address (X_M'', Y_M'') at the frame period based on the equations (72) and (72). The thus generated read address (X_M'', Y_M'') is respectively supplied to the video signal frame memory 22 and the key signal frame memory 23. As a result, as shown in FIG. 14B, the shadow video signal V_6 is outputted from the frame memory 22, and the shadow key signal K_8 is outputted from the frame memory 23.

In the real shadow generator 50 into which the shadow key signal K_8 outputted from the frame memory 23 is inputted, the real shadow control unit 503 reads out corresponding gain data from a table comprising parameters and gain data stored in the ROM 504 based on the parameter H_S, and supplied the gain data to the gain control circuit 500. Accordingly, the gain control circuit 500 supplies the gain corresponding to the gain data supplied from the real shadow control unit 503 to the inputted shadow signal.

The shadow key signal outputted from the gain control circuit 500 is inputted to the horizontal LPF 501 and the vertical LPF 502. The real shadow control unit 503 reads out corresponding coefficient data from the table (see FIG. 19C) comprising H_S and the filter coefficient data stored in the ROM 504 of the real shadow

control unit 503 based on the value of the H_s used as the inputted depth information in this embodiment. This filter coefficient data is supplied to the horizontal LPF 501. The horizontal LPF 501 multiplies the inputted shadow key signal with the file coefficient data from the real shadow control unit 503, and outputs a multiplied output. Then, the real shadow control unit 503 reads out corresponding coefficient data from the table (see FIG. 19C) comprising H_s and the filter coefficient data stored in the ROM 504 of the real shadow control unit 503 based in the inputted H_s, and supplies the thus read-out filter coefficient data to the vertical LPF 502. The vertical LPF 502 multiplies the shadow key signal from the horizontal LPF 501 with the filter coefficient data read out by the real shadow control unit 503 and output a multiplied result as the real shadow key signal K'_6 that is finally outputted from the real shadow generator 50. Accordingly, as shown in FIG. 19A, the contour of the data of the shadow S near the object O becomes clear because the multiplied filter coefficient data near the object O increases. Then, as the shadow comes away from the object O, the value of the multiplied filter coefficient data decreases so that the contour of the data of the shadow S becomes unclear (blurred).

Incidentally, although the manner in which the contour of the data of the shadow becomes unclear progressively cannot be illustrated for the sake of the sheets of drawing, in actual practice, the shadow becomes unclear progressively as the shadow comes away from the object.

The combiner 30 receives the object video signal V_2 and

the object key signal K_2 from the object signal generating unit 10, also receives the shadow video signal V_6 and the real shadow key signal K_6' from the shadow signal generating unit 20, and generates the mixed video signal V_{mix}'' and the mixed key signal K_{mix}'' on the basis of the equation (b). The mixer 40 receives the background video signal V_{BK} supplied from the outside, the mixed video signal V_{mix}'' outputted from the combiner 30 and the mixed key signal K_{mix}'', and generates the output video signal V_{OUT} on the basis of the equation (d).

(11) Effects of the Invention:

According to the present invention, the gain characteristic corresponding to the depth information is controlled and the filtering characteristic corresponding to the depth information is controlled, whereby the more real shadow relative to the object is generated and the image of this shadow, the object image and the background image are synthesized. Therefore, by the simple arrangement and the simple processing, the more real shadow corresponding to the distance from the object image may be added to the target object image at a high speed.

Further, without forming a desired image by separate operations with the object and shadow video special effect apparatus, the more real shadow and the object may be synthesized by the simple operation.

Furthermore, since the desired image may be generated based on the operator's parameters, there is then achieved the effect in which a desired image can be generated without enormous

time unlike the computer graphics.

FIELD OF INDUSTRIAL APPLICABILITY

The special effect apparatus of this invention may be applied to the case such as when a special effects image is generated by the broadcasting station image processing apparatus.

CLAIMS

1. In a special effects apparatus for effecting a special effects processing on an object indicated by a video signal and a shadow of said object, said special effects apparatus comprising:

gain control means for controlling a gain of an image of a shadow of an object;

filtering means for filtering an image of said shadow;

control means for controlling a gain of said gain control means in response to depth information of said shadow and controlling a filtering characteristic of said filtering means in response to the depth information of said shadow; and

synthesizing means for synthesizing an image of a shadow of said object outputted under control of said control means, an image of said object and an image serving as a background of said object.

2. A special effects apparatus as claimed in claim 2, wherein said control means includes memory means for storing gain characteristic data corresponding to said depth information and filtering characteristic data and said control means controls a gain of said gain control means in response to the gain characteristic data stored in said memory means and controls the filtering characteristic of said filtering means in response to the filtering characteristic data stored in said memory means.

3. A special effects apparatus as claimed in claim 1, wherein said filtering means is comprised of a low-pass filter.

4. In a special effects apparatus for effecting a special effects processing on an inputted source video signal, said special effects apparatus comprising:

object signal generating means for effecting a first image transform processing on said source video signal to generate an object signal indicative of a target image;

shadow signal generating means for effecting a second image transform processing on said source video signal to generate a shadow signal corresponding to said target image; and

synthesizing means for receiving the object signal outputted from said object signal generating means and the shadow signal outputted from said shadow video signal generating unit and synthesizing said object signal, said shadow signal and a background signal corresponding to said source video signal to generate an output video signal, wherein said shadow signal generating means includes a gain control means for controlling a gain of said shadow signal corresponding to said source video signal, filtering means for filtering said shadow signal, depth information generating means for generating depth information corresponding to said shadow signal and control means for controlling a gain of said gain control means based on said depth information from said depth information generating means and controlling a filtering characteristic of said filtering means based on said depth information.

5. A special effects apparatus as claimed in claim 4, wherein the shadow signal inputted to said shadow signal generating mean is inputted to said gain control means from which it is outputted as a shadow signal whose gain was controlled and said shadow signal with said gain controlled is inputted to said filtering means in which it is filtered and outputted from said filtering means as a shadow signal.

6. A special effects apparatus as claimed in claim 4, wherein said filtering means is comprised of a low-pass filter.

7. A special effects apparatus as claimed in claim 4, wherein said control means includes memory means for storing gain characteristic data corresponding to said depth information from said depth information generating means and filtering characteristic data and said gain characteristic data and said filtering characteristic data are supplied from said memory means to said gain control means and said filtering means in response to said depth information, respectively.

8. A special effects apparatus as claimed in claim 4, wherein said object signal generating means includes memory means for storing said inputted source video signal and read address generating means for generating a read address so as to read said source video signal from said memory means at a predetermined unit and said first image transform processing processes said object

video signal read out from said memory means by said read address as a target image.

9. A special effects apparatus as claimed in claim 4, wherein said shadow video signal generating means includes memory means for storing said inputted source video signal and read address generating means for generating a read address so as to read said source video signal from said memory means at a predetermined unit sand said second image transform processing processes said shadow video signal read out from said memory means by said read address such that said shadow video signal is outputted as a shadow signal corresponding to said target image.

10. A special effects apparatus, wherein said synthesizing means is comprised of first synthesizing means for receiving said object signal from said object signal generating means and said shadow signal from said shadow signal generating means and synthesizing said inputted respective signals to output a mixed signal and second synthesizing means for synthesizing said mixed signal and said background signal to output an output video signal.

11. In a special effects apparatus for effecting a special effects processing on an inputted source video signal and a source key signal corresponding to said source video signal, said special effects apparatus comprising:

object signal generating means for receiving said source video signal and said source key signal and effecting a first image transform processing on said inputted source video signal and said inputted source key signal to generate an object video signal and an object key signal corresponding to a target image;

a shadow signal generating means for receiving said source video signal and said source key signal and effecting a second image transform processing on said inputted source video signal and said inputted source key signal to generate a shadow video signal and a real shadow key signal corresponding to said target image; and

synthesizing means for receiving the object video signal and the object key signal outputted from said object signal generating means, said shadow video signal and said real shadow signal from said shadow signal generating means and a background signal corresponding to said source video signal and synthesizing said inputted respective signals to generate and output an output video signal, wherein said shadow signal generating means includes shadow key signal generating means for generating a shadow key signal corresponding to said target image for said inputted source key signal, gain control means for controlling a gain of the shadow key signal outputted from said shadow key signal generating means, filtering means for filtering said shadow key signal, depth information generating means for generating depth information corresponding to said shadow signal and control means for controlling a gain of said gain control means based on said depth

information from said depth information generating means and controlling a filtering characteristic of said filtering means based on said depth information.

12. A special effects apparatus as claimed in claim 12, wherein said filtering means is comprised of a low-pass filter.

13. A special effects apparatus as claimed in claim 12, wherein the shadow key signal outputted from said shadow key signal generating means of said shadow signal generating means is outputted as a shadow key signal whose gain was controlled by said gain control means and the shadow key signal with the gain controlled is inputted to said filtering means, in which it is controlled in filtering characteristic and outputted as a real shadow key signal.

14. A special effects apparatus as claimed in claim 12, wherein said control means of said shadow signal generating unit includes memory means for storing gain characteristic data corresponding to said depth information from said depth information generating means and filtering characteristic data and said gain characteristic data and said filtering characteristic data are respectively supplied to said gain control means and said filtering means in response to said depth information.

15. A special effects apparatus as claimed in claim 12, wherein said synthesizing means includes first synthesizing

means for receiving said object video signal and said object key signal from said object signal generating means, said shadow video signal and said real shadow key signal from said shadow signal generating means and generating a mixed video signal and a mixed key signal by synthesizing said respective inputted signals and second synthesizing means for generating said output video signal from said mixed video signal and said mixed key signal from said first synthesizing means and said background signal.

16. A special effects apparatus as claimed in claim 12, wherein said object signal generating means includes first memory means for memorizing said source video signal, second memory means for memorizing said source key signal and read address generating means for generating read addresses such that said source video signal and said source key signal stored in said first memory means and said second memory means are read out from said respective memory means and supplying said read addresses to said first memory means and said second memory means and said first image transform processing outputs said object video signal and said object key signal read out from said first memory means and said second memory means as said target image.

17. A special effects apparatus as claimed in claim 12, wherein said shadow signal generating means includes third memory means for memorizing said source video signal, fourth memory means for memorizing said source key signal and read address

generating means for generating read addresses such that said source video signal and said source key signal memorized in said third memory means and said fourth memory means are read out from said respective memory means and supplying said read addresses to said third and fourth memory means and said second image transform processing effects a processing such that said shadow video signal and said shadow key signal read out from said third memory means and said fourth memory means are outputted and said shadow video signal is outputted as a shadow video signal corresponding to said target image.

18. In a special effects method for effecting a special effects processing on an object indicated by an inputted video signal and a shadow of said object, said special effects method comprising the steps of:

a gain step for controlling a gain of an image indicating the shadow of said object;

a filtering step for filtering the image of said shadow;

a control step for controlling a gain of said gain step in response to depth information of said shadow and controlling a filtering characteristic of said filtering step in response to the depth information of said shadow; and

a synthesizing step for outputting an output video signal by synthesizing an image of a shadow of said object outputted under control of said control step, an image of said object and an image serving as a background of said object.

19. A special effects method as claimed in claim 18, wherein said control step controls said gain at said gain step by gain characteristic data corresponding to said depth information stored in memory means and filters an image of said shadow at said filtering step by filtering characteristic data corresponding to aid depth information stored in said memory means.

20. In a special effects method for effecting a special effects processing on an inputted source video signal, said special effects method comprising the steps of:

an object signal generating step for generating an object signal indicative of a target image by effecting a first image transform processing on said source video signal;

a shadow signal generating step for generating a shadow signal corresponding to said target image by effecting a second image transforming processing on said source video signal; and

a synthesizing step for receiving said object signal, said shadow signal and said source video signal and outputting an output video signal by synthesizing said respective inputted signals, wherein said shadow signal step includes a gain control step for controlling a gain of said shadow signal corresponding to said source video signal, a filtering step for filtering said shadow signal, a depth information generating step for generating depth information corresponding to said shadow signal and a control step for controlling a gain of said gain control step based on said depth information from said depth information generating step and

controlling a filtering characteristic of said filtering step based on said depth information.

21. In a special effects method comprising the steps of:

an object signal generating step for generating an object signal indicating a target image by effecting a first image transform processing on an inputted source video signal;

a shadow signal generating step for generating a shadow signal corresponding to said target image by effecting a second image transform processing on said source video signal; and

a synthesizing step for receiving the object signal generated at said object signal generating step and the shadow signal generated at said shadow video signal generating step and outputting an output video signal by synthesizing said object signal, said shadow signal and a background signal corresponding to said source video signal, said shadow signal generating step including a gain control step for controlling a gain of said shadow signal corresponding to said source video signal, a filtering step for filtering said shadow signal, a depth information generating step for generating depth information corresponding to said shadow signal and a control step for controlling a gain of said gain control step based on depth information from said depth information generating step, wherein said filtering step is executed by a low-pass filter.

22. A special effects method as claimed in claim 21, wherein said control step includes a memorizing step for memorizing gain characteristic data corresponding to said depth information from said depth information generating step and filtering characteristic data and said gain characteristic data and said filtering characteristic data are supplied from said memorizing step to said gain control step and said filtering step in response to said depth information, respectively.

23. A special effects method as claimed in claim 21, wherein said object signal generating step includes a memorizing step for memorizing said inputted source video signal and a read address generating step for generating a read address such that said source video signal is read out from said memorizing step at a predetermined unit and said first image transform processing processes said object video signal read out from said memorizing step by said read address as a target image.

24. A special effects method as claimed in claim 21, wherein said shadow video signal generating step includes a memorizing step for memorizing said inputted source video signal and a read address generating step for generating a read address such that said source video signal is read out from said memorizing step at a predetermined unit and said second image transform processing outputs said shadow video signal read out from said memory means by said read address as a shadow signal corresponding

to said target image.

25. A special effects method as claimed in claim 21, wherein said synthesizing step includes a first synthesizing step for receiving said object signal from said object signal generating step and said shadow signal from said shadow signal generating step and outputting a mixed signal by synthesizing said respective inputted signals and a second synthesizing step for outputting an output video signal from said mixed signal and said background signal.

26. In a special effects method for effecting a special effects processing on an inputted source video signal and a source key signal corresponding to said source video signal, said special effects method comprising the steps of:

an object signal generating step for generating a object video signal and an object key signal corresponding to a target image by effecting a first image transform processing on an inputted source video signal and a source key signal corresponding to said source video signal;

a shadow signal generating step for generating a shadow video signal and a real shadow key signal corresponding to said target image by effecting a second image transform processing on said source video signal and said source key signal; and

a synthesizing step for receiving the object video signal and the object key signal from said object signal generating

step, the shadow video signal and the real shadow key signal from said shadow signal generating step and a background signal corresponding to said source video signal and generating an output video signal by synthesizing said respective inputted signals, wherein said shadow signal generating step includes a shadow key signal generating step for generating a shadow key signal corresponding to said target image for said inputted source video signal, a gain control step for controlling a gain of a shadow key signal outputted from said shadow key signal generating step, a filtering step for filtering said shadow key signal, a depth information generating step for generating depth information corresponding to said shadow signal and a control step for controlling a gain of said gain control step based on said depth information and controlling a filtering characteristic of said filtering step based on said depth information.

27. A special effects method as claimed in claim 26, wherein said filtering step is executed by a low-pass filter.

28. A special effects method as claimed in claim 26, wherein a shadow key signal outputted from said shadow key signal generating step in said shadow signal generating step is outputted as a shadow key signal whose gain was controlled by said gain control step and the shadow key signal whose gain was controlled is inputted to said filtering step, in which it is controlled in filtering characteristic and outputted as a real shadow key signal.

29. A special effects method as claimed in claim 26, wherein said control step in said shadow signal generating step includes a memorizing step for memorizing gain control data corresponding to said depth information from said depth information generating step and filtering characteristic data and said gain characteristic data and said filtering characteristic data are supplied to said gain control step and said filtering step in response to said depth information, respectively.

30. A special effects method as claimed in claim 26, wherein said synthesizing step includes a first synthesizing step for receiving said object video signal and said object key signal from said object signal generating step, said shadow video signal and said real shadow key signal from said shadow signal generating step and generating a mixed video signal and a mixed key signal by synthesizing said respective inputted signals and a second synthesizing step for generating said output video signal from the mixed video signal and the mixed key signal from said first synthesizing step and said background signal.

31. A special effects method as claimed in claim 26, wherein said object signal generating step includes a first memory step for memorizing said source video signal, a second memory step for memorizing said source key signal and a read address generating step for generating read addresses used to read out said source video signal and said source key signal stored at said first memory

step and said second memory step from said respective memory steps and supplying said read addresses to said first memory step and said second memory step and said first image transform processing outputs said object video signal and said object key signal read out from said first memory step and said second memory step by said read addresses as said target image.

32. A special effects method as claimed in claim 26, wherein said shadow signal generating step includes a third memory step for memorizing said source video signal, a fourth memory step for memorizing said source key signal and a read address generating step for generating read addresses for reading out said source video signal and said source key signal respectively stored in said third memory step and said fourth memory step from said respective memory steps and supplying said read addresses to said third memory step and said fourth memory step and said second image transform processing effects a processing such that said shadow video signal and said shadow key signal respectively read out from said third memory step and said fourth memory step by said read addresses are outputted and said shadow video signal is outputted as a shadow video signal corresponding to said target image.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/01249

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^{6} H04N5/262

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^{6} H04N5/262, G06T11/00-11/80

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1997
Kokai Jitsuyo Shinan Koho 1971 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 1-293078, A (NEC Corp.), November 27, 1989 (27. 11. 89) (Family: none)	1 - 32
A	JP, 4-227171, A (NEC Corp.), August 17, 1992 (17. 08. 92) (Family: none)	1 - 32
A	JP, 4-315274, A (Sony Corp.), November 6, 1992 (06. 11. 92) & GB, 2256109, A & US, 5282262, A	1 - 32
A	JP, 7-93585, A (Dainippon Screen Mfg. Co., Ltd.), April 7, 1995 (07. 04. 95) (Family: none)	1 - 32
A	JP, 1-144869, A (NEC Corp.), June 7, 1989 (07. 06. 89) (Family: none)	1 - 32
A	JP, 63-59276, A (NEC Corp.), March 15, 1988 (15. 03. 88) (Family: none)	1 - 32
A	JP, 5-207364, A (NEC Corp.),	1 - 32

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
July 7, 1997 (07. 07. 97)	July 23, 1997 (23. 07. 97)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/01249

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	August 13, 1993 (13. 08. 93)(Family: none)	
A	JP, 2-59982, A (Nippon Telegraph & Telephone Corp.), February 28, 1990 (28. 02. 90)(Family: none)	1 - 32
A	JP, 5-54151, A (Brother Industries, Ltd.), March 5, 1993 (05. 03. 93)(Family: none)	1 - 32